Technische Hochschule Georg Agricola

Competence Network Security Research
(Kompetenznetz Sicherheitsforschung)

Conference Proceedings

Days of Security Research
June 14th- 16th 2023

112Rescue | Dortmund (Germany)

in cooperation with:
Research Center of Post-Mining at Technische Hochschule Georg Agricola University, Bochum (Germany)
Association of Fire Services North Rhine-Westphalia (Verband der Feuerwehren Nordrhein-Westfalen), Wuppertal (Germany)
Dortmund Trade Fair (Messe Dortmund GmbH), Dortmund (Germany)

Published by
Dr. Bodo Bernsdorf
Technische Hochschule Georg Agricola University

October 2024

Imprint

Conference Proceedings Security Research Days 2023

Published by

Dr. Bodo Bernsdorf
Research Center of Post-Mining
Technische Hochschule Georg Agricola University, Bochum

Under collaboration of Cinja Bösel, Julian Jaeckel, Laura Klein, Dr. Yvonne Liebermann, Quynh Anh Nguy Thi und Nyein Than Thar Lwin

Address

Herner Straße 45

44787 Bochum

Open Access

ISBN 978-3-949115-17-2

The Days of Security Research are an initiative of the free association of researchers in the Competence Network for Security Research.

http://www.kompetenznetz-sicherheitsforschung.de

The Technische Hochschule Georg Agricola University (THGA) is a state-recognized university of the DMT-Gesellschaft für Lehre und Bildung mbH, Bochum (responsible body). It is represented by its President Prof. Susanne Lengyel.

Technische Hochschule Georg Agricola

Conference Proceedings

Days of Security Research

June, 14th – 16th 2023

The Days of Security Research were organized jointly with the Research Committee of the NRW Association of Fire Services. Trade Fair Dortmund generously supported the event by providing the stage and high-quality event technology. Many thanks to both organizations!

Note:

The technical terms used in the publications are part of their established technical language. They are therefore not subject to the rules of the new German orthography

Authors:

Lukas Arzoumanidis
Michael Bartz
Bodo Bernsdorf
Xabier Blanch Gorriz
Patrick Brausewetter
Anette Eltner
Sven Gedicke
Bernhard Glittenberg
Iris Gräßler
Jens Grundmann
Benjamin Haske
Jan-Henrik Haunert
Ralf Hedel
Noah Herschbach
Michael Hieb
Marvin Janßen
Ivana Kruijff-Korbayova
Oliver Krüger
Susanna Kunzmann
André Kutscher
Tanja Morgenstern
Jens Pottebaum
Sylvia Pratzler-Wanczura
Monika Rode
Tobias Rudolph
Nicola Rupp
Max Schnepf
Jonas Schubert
Jan Seitz
Philipp Toschka
Moritz Watermann

Technische Hochschule Georg Agricola

Inhalt

EDITORIAL

Bodo Bernsdorf

Technische Hochschule Georg Agricola University

The Security Research Competence Network was launched at the annual conference of the Association for the Promotion of German Fire Protection (vfdb) in Würzburg. One of the main motivations was to establish a joint specialist conference where security researchers could exchange ideas and present research findings to discuss them with a specialist audience. When the 112Rescue trade fair was launched in 2023, the founding members of the Security Research Competence Network, the Association of Fire Services and the Technische Hochschule Georg Agricola University, were ready and willing to seize the opportunity and implement the Security Research Days as an exchange platform in the Competence Network. Together with Trade Fair Dortmund, the topics were addressed and a call for papers was issued in fall 2022. This call was also intended to directly achieve the second goal: The security research community still lacked a national journal in which their findings could undergo a peer review process and subsequently be published for the scientific public.

Both were implemented with the first Days of Security Research from June 14-16, 2023 and the conference proceedings presented here.

The establishment of a peer-reviewed journal is the first milestone. These articles are the result of presentations at specialist conferences and were subsequently subjected to a review. Two key requirements were implemented for this:

- The articles undergo an open peer review process: The identities of authors and reviewers are known to each other and it was possible to exchange information intensively. There was the option to clarify comments directly and to better understand the wishes of the reviewers or to clarify them in context.
- Due to the lack of a established review community, the presenters were offered the opportunity to become reviewers for articles by other presenters. Two reviewers each worked on one article. In most cases, the first review was carried out by people who had experienced the lecture event themselves and contributed to it (Review 1). These were supplemented by colleagues from the scientific committee and interested parties from the Competence Network for Security Research.

The publisher is confident that this will ensure high scientific quality. The conference proceedings are offered as open access via the THGA's publication server - another important milestone in security research. A Document Object Identifier (DOI) has been assigned to the conference proceedings as such, but also to each individual article[1]. The articles are therefore freely accessible and easy to search. We would like to thank the THGA library team for this.

[1] Due to technical problems with the introduction of the new library system at the THGA, the allocation of the doi will be delayed until fall 2024 and will be entered below

Technische Hochschule Georg Agricola

The Scientific Commitee in alphabetical order:

Dr. Bodo Bernsdorf (Chairman Research Committee VdF NRW)

Christian Eichhorn (Vice President VdF NRW)

Tim Glanert (Research Committee VdF NRW)

Robert Grafe (Managing Director German Rescue Robotic Center | Deutsches Rettungsrobotik-Zentrum DRZ)

Dr. Dieter Hennecke (Research Committee VdF NRW)

Dr. Vanessa Kogel (Research Committee VdF NRW)

Prof. Dr. Christian Melchers (Vice President THGA, Head of Reserach Center of Post-Mining)

Dr. Mark Niemann (Research Committee VdF NRW)

Dr.-Ing. Sylvia Pratzler-Wanczura (Scientific Director Institute of Fire and Rescue Technology | Institut für Feuerwehr- und Rettungstechnologie)

Dr. Monika Rode (Scientific Coordinator Institute of Firefighting | Institut der Feuerwehr NRW)

Prof. Dr. Tobias Rudolph (Scientific Chairman Geomonitoring in Post-Mining)

Dr. Jonas Schubert (DermaPurge GmbH and Leibniz-Institute of Polymer Research, Dresden)

Note:

A link to download the presentation is provided after each article. The link leads to the NRW Science Cloud SCIEBO.

By using the link, users agree to be redirected to external sources. The publisher accepts no responsibility for links in the presentations.

Note:

The figures in this translation are taken from the original, thus, mostly presented in German Language.

Technische Hochschule Georg Agricola

Days of Security Research

Day 1: June 14th 2023

Session: Introduction

Foreword

Tobias Rudolph

Technische Hochschule Georg Agricola University

As the professor responsible for the scientific field of geomonitoring in post-mining at the Research Center of Post-Mining at Technische Hochschule Georg Agricola University, it has become abundantly clear in recent years that the environment is changing. With a professional background in the gas and oil industry, you can quickly recognize how weather and atmospheric conditions affect critical infrastructure. Be it in terms of plant technology or the requirements of the storage industry, for example (geopolitical conflicts do the rest). As a geologist and environmental scientist, these connections are obvious. This is because the effects of drought and periods of drought alternating with considerably longer periods of precipitation and heavy rainfall events with extreme increases in precipitation not only change the usual weather and weather patterns in Germany, but also the landscape itself. They also have an extreme impact on the infrastructure.

Environmental and geomonitoring have had methods at their disposal for many years to detect, document and subsequently observe such changes on a regular basis. Here, research can contribute knowledge to hazard prevention that was only of importance for anthropogenic climate change in environmental monitoring. Satellites and drones, for example, are tools whose sensors can also be used to gain knowledge in the field that significantly changes the assessment of the situation. This becomes clear, for example, with thermal infrared images. Here, the sensors provide information about wavelengths that the human eye cannot see and therefore offer the incident command an additional "sense" when determining the situation. The same also applies to multi-spectral and hyperspectral cameras, which are regularly used to assess vegetation, for example. Procedures can be developed here to prevent forest fires, for example. The possibilities are manifold.

But it requires good training. Specialists must be deployed in order to conduct targeted reconnaissance using such sensors. The Bundeswehr, for example, has the function of an aerial image interpreter. And, as the KIWA article makes clear, artificial intelligence offers approaches for evaluating the constantly growing volumes of data in advance. An incredible added value - even if AI cannot make any decisions.

This is just one small aspect of the changing world of operations. The early days of security research have shown this. Whether it's the climate transition, the mobility transition or the constant decrease in specialist personnel: everything has an impact on the deployment process, as the following articles will show - and the presentations have already strikingly demonstrated.

Research is an essential part of this. This is because procedures that are already established cannot simply be integrated into operations. Further developments or even special developments must be adapted to the issues of emergency response. Therefore, this is not necessarily basic research. This will presumably be able to be driven forward in a more targeted manner in the respective specialist sciences. What is needed is the analysis of known procedures and approaches

Technische Hochschule Georg Agricola

and practice-oriented research that makes such procedures adaptable in emergency response. Basic research should and must not be excluded.

Both are established at universities of applied sciences AND universities. The same applies to non-university research institutions. This becomes clear in the combination of users, companies and researchers presented by the Competence Network for Security Research. Everyone must work together to tackle science and research, but also subsequent practical development. The associations in the network are once again responsible for lobbying and pooling research requirements.

In this respect, these conference proceedings show the way. In the authorship, all the institutions in question are working together to bring the results of the researchers closer to the emergency services. It would be positive if the network could be expanded, the Days of Security Research could become established in the future and the corresponding high-quality scientific contributions in the conference proceedings could become a pool of high-quality research results.

The competence network for security research – A review after the first year

Bodo Bernsdorf

Technische Hochschule Georg Agricola University | Research Committee VdF NRW

Abstract

The Competence Network for Security Research had been in existence for one year in May 2023. During this time, it has developed well with 44 participating organizations. The four founding partners are VdF NRW, vfdb, AK Forschung der AGBF NRW and THGA, Bochum, focused on establishing a platform to promote scientific work according to good and recognized standards in the field of security research. The initial intention was to establish a specialist event and an online-based open access magazine with a peer review process. The first goal was realized with the Days of Security Research in June 2023, and the second goal is approaching.

The article also describes the geographical distribution of the member organizations and an initial evaluation of the areas of interest. An attempt is made to evaluate the latter against the current background of the funding landscape.

Background

The Competence Network for Security Research (KN SiFo) was launched on 23 May 2022 at the Würzburg Annual Conference of the Association for the Promotion of German Fire Protection, vfdb e.V., with a lecture and a presentation of the website. The network is a joint initiative of various organizations:

- Association of Fire Services North Rhine-Westphalia (VdF NRW e.V.)
- Association for the Promotion of German Fire Protection (vfdb e.V.)
- Research working group of the working group of the heads of the professional fire brigades in North Rhine-Westphalia (AK FO AGBF NRW)
- Research Centre of Post-Mining of the Technische Hochschule Georg Agricola University (FZN, THGA)

The latter is responsible for hosting the network.

The primary aim of the network is to bring together organizations in the field of BOS and security research - both geographically and thematically. The aim is to create transparency among those who conduct research in the field of civil security and are looking for partners for joint activities.

Technische Hochschule Georg Agricola

Examples include joint applications for research projects in relevant funding frameworks. Research institutions and universities, but also interested users, small and medium-sized enterprises, are of great value here. It can be assumed that a stronger, jointly organized practical orientation will more frequently lead to a product idea or a process that is later used in reality. The constellation should therefore help to safely cross the "valley of death" of a research project (Pratzler-Wanczura & Aschenbrenner 2022). The network includes partners from associations, companies, fire brigades and aid organizations, authorities and research institutions or universities. All are committed to working together on funding applications, but also to providing the often-necessary co-financing. The latter is a major obstacle, as certain funding frameworks such as KMU - Innovative generally welcome applications from small and medium-sized enterprises, but the funding rate is only a maximum of 45% of the project costs (see BMBF 20217). As it is also required that the SME should receive at least 50% of the total funding amount, a small company has to co-finance large amounts from its operating business. For example, if an SME has a university partner and a research partner such as a Fraunhofer Institute, which each apply for 100,000 euros in funding and receive 100% of this funding, the SME itself must submit an application for a project volume of around 445,000 euros, which is then funded at 45% = 202,500 euros. This means that it has fulfilled all the conditions, but must ask itself how it can generate the remaining 242,500 euros from its current business. SMEs in the network therefore plays a central role in funding programs that are otherwise not accessible to the other partners in the network.

Other objectives include joint events, such as the "Days of Security Research", which have now been organized for the first time, with a premiere at the 112Rescue trade fair in Dortmund, which will be held for the first time in 2023. The peer review process is also intended to promote high-quality publications in the field of security research. The peer review process ensures that researchers' work and statements are recognized by the scientific community. Some funding organizations attach great importance to good scientific practice, which can be documented in this way. The introduction of document object identifiers (doi) for all types of scientific work or free access to literature via the open access approach for scientific work in security research is also a focus of activities.

The network has no project funding from a subsidy pot. In this respect, it is ultimately - like the BOS in the entire DACH region - primarily based on voluntary work. Despite this, it has achieved astonishing growth in its first year.

In addition to the initial publications on the network, this article aims to clarify the background and objectives. At the same time, this article also aims to reveal the areas of interest represented by the participating organizations. It is not the classic topics of fire protection, but rather modern aspects such as IT, robotics or geoinformation that are the focus of the (user-orientated) researchers. The question of what the reasons are for such a development - the shift towards future-oriented topics in security research - and how funding organizations should best respond to this will be explored.

Networks of Security Research

Security research generally does not work alone. Protagonists are dependent on each other. This is due to the complex network of complex technological approaches that are often available, constantly changing deployment and framework conditions, specific needs of emergency services and ultimately the financial opportunity to try out ideas or even transform them into marketable products (e.g. Gabel et al. 2016). The challenges of recent years have shown this. At the latest after the drought years from 2018 and the subsequent heavy rain disaster in July 2021 or the forest fires from 2022, it is clear to the authorities and organizations with security tasks (BOS) that the challenges have changed and will increasingly change.

All too often, research funding is not aimed at concrete implementation. There are various obstacles to this. Essentially, funding from federal organizations or the EU is not about funding development, but - merely - funding research work. It is still a long way from a good solution to commercialization. Too many projects therefore end up in the drawers of the institutes and are not pursued further. Pratzler-Wanczura & Aschenbrenner (2022) describe this trend as the "valley of death" that lies between research and the market.

From various conversations the author has had with investors, it is also clear that the largely municipalized fire and disaster protection market is very unattractive: Bringing innovation into an environment that is characterized by an extremely large number of decision-makers and is dependent on tight budgets and dual budgets is hardly attractive for companies. This is because in today's world, a research and development lead is at best six months, but not several years.

Accordingly, there is a need for networks in which those interested in research can find each other and exchange ideas. The aim must be to be able to act in a more practice-orientated way. Practical orientation relates to two aspects: In terms of content, research should not bypass the needs of the emergency services. This can be achieved by involving the organizations that use them. In terms of time, the required equipment or procedures should be integrated into the market quickly. This can be achieved in part by involving SMEs that think in business terms. On the other hand, the municipalized fire service in particular is an extremely fragmented market. Here again, it is up to the procuring authorities and even more so the politicians, as they create the framework conditions. Relevant networking initiatives show the necessity of this. For example, the Federal Ministry of Education and Research (BMBF) ran the "Security Research Map" for a while, an interactive map of funded projects (BMBF n.d.[1]). Companies, universities, research institutions and authorities successfully registered here and interested parties were able to find potential partners simply by describing the research field. This overview is currently not available, but according to representatives of VDI Technologiezentrum GmbH (project management organization for the BMBF and the "Research for Civil Security" funding framework), it will be reactivated in the future.

In Austria, too, there is such a bracket with "KIRAS - Security Research", which offers a Security Research Map (SeReMa) for national research projects (FFG n.d). In contrast, SeReMa, which also sees itself as a security research database, has established itself with an international focus (SEREN4 n.d.). The project was funded in the Horizon 2020 program. There is a tab for national platforms on the SeReMa homepage. It is noticeable that there is only a link to the Austrian KIRAS network, but not to the BMBF network (cf. https://www.security-research-map.eu//index.php?file=maps.htm).

There are also a large number of topic-specific networks. Be it at association level or in research networks. The website www.kompetenznetz-sicherheitsforschung.de lists seven other networks that have similar intentions to those of the KN SiFo. One example is the Research Network of German Users (ForAn) (BMBF n.d. [2]). ForAn brings together users from the fields of police and non-police hazard prevention as well as operators of critical infrastructures. Quote:

Networking strengthens civil security research as a strategic instrument for users so that they can better adapt to future challenges. ForAn supports its members in acquiring European funding from the Horizon Europe research framework program. Applied civil security research only works in a triad of users, research institutions and industry. (BMBF n.d. [2] Homepage).

This propagates ideas similar to those of the Competence Network for Security Research, which raises the question of what added value a new network has to offer. The answers are simple: The KN SiFo focusses on institutions that are interested in and actively involved in security research. Similar to the research maps cited, the spatial component plays a role, as spatial proximity often simplifies co-operation and can even create joint markets (industry clusters are a model: Porter 2000). Thematically, the network was initially narrowed down to 23 areas of interest in order to limit the topics to security research issues. An openly organized topic query did not appear to be expedient for the foundation. While the cited networks focus more or less on specific issues and related funding programs, scientific exchange also plays a major role in the KN SiFo (specialist conference, peer review magazine). When the network was founded, a "Security Research Day" was already planned and focused on as the first project. The lack of a scientifically sound pool of publications (magazine, specialized journal) and the possibility of having one's own work subjected to peer review was also addressed when the network was founded. These ideas have been addressed with the "Days of Security Research" organized for the first time at the 112Rescue in Dortmund and the present conference proceedings. The future will have to show whether these achievements can be sustained.

Such arguments seemed reason enough for the founding organizations to launch the network at the vfdb annual conference on May 23rd 2022 (Bernsdorf 2022[1,2]). A co-operative alliance forms the core: the NRW Association of Fire Services, the Association for the Promotion of German Fire Protection, the Research Working Group of the Working Group of the Heads of the Professional Fire Services in NRW and the Technische Hochschule Georg Agricola University initiated this network.

The idea of an independant Network

Competence Network for Security Research vs. subsidized Networks

The idea was therefore to establish an overarching network of expertise that is not dependent on or limited to a sponsoring institution. The focus is on good scientific work in the field of security research, which can result in partner constellations for joint research and development projects. As good and important as the SeReMa initiative cited is, if a network can only exist if it is backed by appropriate funding (e.g. SEREN 5 with funding from Horizon 2020), it may be doomed to failure because there are few funding institutions at federal or EU level that provide funds for research work that are not project-financed. One possibility is offered by the "Pact for Research and Innovation" (PFI) (BMBF [3]) - with the main restriction that it only funds the large non-university research institutions in Germany and the German Research Foundation (see below). Once project funding has ended, however, the protagonists are usually absent and have to finance themselves through new projects, etc. A competence network that is independent of such funding must be intrinsically founded - from within and from its own motivation. From a core, the burden is distributed across different shoulders. In the case of the Competence Network for Security Research, these are the four founding organizations that provide their own resources.

Challange of security research

The motivation to exchange information at regular intervals and to create an open access magazine that ensures good scientific practice is certainly there. However, as in the other networks, joint work can also motivate the improvement of the funding landscape - a task that the strong, founding organizations can achieve in the background and take up impulses from the network. Problematic: In many cases, security research involves interdisciplinary approaches and / or the transfer of often well-known technologies and processes for use in the area of civil, non-police hazard defense. As a result, security research often has the stigma of actually being pure development work. After all, the technology has already been "invented" and the process has already been "researched". To put it bluntly: From the author's point of view, this is far from the case. Just because a satellite- or drone-borne hyperspectral sensor can detect near-surface minerals in mineral deposits, it is far from clear how this knowledge can be transferred to questions of hazardous substance analysis in CBRN applications, what accuracies can be achieved and whether concentrations can be derived. The latter in particular seems unlikely with current remote sensing methods without additional measurements. The targeted transfer for the application of such technologies in the field of fire and disaster protection has a considerable research component! This argumentative battle of security researchers begins with the fact that the German Research Foundation (DFG), the largest German research funding organization supported by the federal and state governments, does not list security research as a subject area (DFG 2023[1], DFG 2023[2]). The subject classification is classic. As a result, 3.9 billion euros in funding volume essentially bypasses security research. Consequently, there is no explicit SiFo funding among the 31,750 projects funded in 2022. This is because among the 49 review boards existing in 2023, security research is at best represented in a concealed manner (all information from the 2022 annual report; DFG 2023[1], see Figure 1).

Security researchers must assign themselves to a specific subject area in order to compete with excellent basic researchers with their mostly interdisciplinary and application-orientated approaches within this subject area. A search for security research projects in the annual report only reveals a "Joint Committee of the DFG and the German National Academy of Sciences Leopoldina on the Handling of Security-Related Research (DFG 2023[1], p. 176), which is more concerned with the ethical principles of security-related research than with security research per se.

The DFG's statutes state:

> § 1 The tasks:
>
> "The German Research Foundation funds research of the highest quality. The focus is on funding projects developed by the scientific community itself in the field of knowledge-driven research. It finances research projects, designs competition areas and carries out procedures for the assessment, evaluation, selection and decision of research proposals. The German Research Foundation helps to shape the framework conditions and standards of scientific work. It maintains a dialogue with society, politics and industry and supports the transfer of knowledge. It advises state and public interest organizations on scientific and science policy issues." (Source: DFG 2023[1], p. 295)

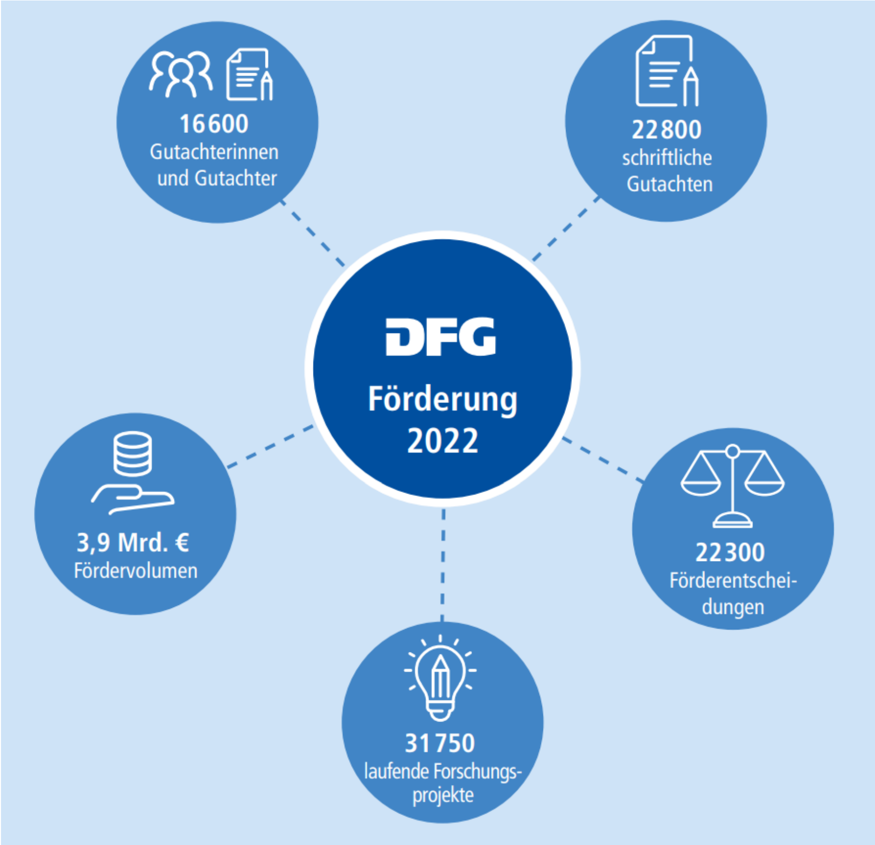


Figure 1: Funding activities of the German Research Foundation 2022 (source: DFG 2023[1], p. 196)

In addition, the "Pact for Research and Innovation" (PFI for short, BMBF (n.d. [3]) - as described - provides non-university, publicly funded research institutions with planning security through continuous budget increases in a research funding initiative of the federal and state governments. It affects the budgets of the Helmholtz Association, the Max Planck Society, the Fraunhofer Society, the Leibniz Association and the German Research Foundation. In return for financial planning security, the scientific organizations have committed themselves to research policy goals; these are above all:

- better networking in the science system
- more international co-operation
- more transfer between science and industry
- "Attracting the best minds for science"
- improvement of equal opportunities

If the statements in §1 and these aspects are considered, it is noticeable that they fit very well with the organizations that are involved in the field of security research. Consequently, the Fraunhofer-Gesellschaft, for example, is also frequently active in the field of security research. However, it is difficult for security researchers outside these non-university research organizations to equate the mostly interdisciplinary and practice-oriented research with "knowledge-driven research" if this is understood more or less as basic research. This is because the transfer of knowledge mentioned in §1 does not refer to the transfer into actual application, a product or process that can be used by fire and disaster protection experts. But this must be the goal of all safety research. The DFG should therefore propose a funding framework that is particularly suitable for interdisciplinary research with a high degree of transfer from existing research areas, whose research and development is knowledge-orientated, but nevertheless so practice-oriented that it leads to noticeable and, above all, timely development boosts in fire and disaster protection.

On the other hand, there are further opportunities for security researchers. Funding programs that are advertised specifically for this environment. The federal ministries in particular are constantly launching new programs in which good applications can be accommodated. These include the Federal Ministry of Education and Research (BMBF), the Federal Ministry for Digital and Transport Affairs (BMDV) and the Federal Ministry of Economics and Climate Protection (BMWK). Explicit reference should be made to the BMBF's "Research for Civil Security" funding framework, which is to be relaunched in 2024 (BMBF n.d. [4]). In 2024, opportunities will again be created for a funding period of a further seven years, which will require this practical relevance in the calls for funding. Although these are also demonstrators at best, the intention to get into practice quickly is always clearly recognizable.

In a joint position paper of the Innovation Cluster Civil Security Research (InCluSiF), the vfdb, the research working group of the AGBF NRW and the German Fire Service Association (DFG), aspects were formulated for the agenda process of the aforementioned update of the funding framework "Research for Civil Security" that appear essential to security researchers in order to bring the research results into use quickly and with practical relevance. Key points include the broad thematic opening of the funding program so as not to restrict the topics too much. This should favour researchers being able to react quickly to new developments. The regular needs assessment (see below), aspects of double funding, the actual transfer of results and administrative aspects of research projects were also addressed (InCluSiF et al. 2022).

The role of a competence network

For various reasons, a strong competence network can be helpful in setting topics. This is because upcoming research topics can be identified and formulated by many member organizations with greater certainty than if they were individual opinions. The KN SiFo therefore has the fundamental task of substantiating the topics from a scientific perspective and addressing them in joint research projects, the symposium and publications. The aim is to complement the initiatives already started/existing in the founding organizations at a scientific level. This will be illustrated with a few examples:

- At a university such as the THGA, for example, this is laid out in so-called "missions" THGA n.d.):
- First Mission: Teaching (studies)
- Second mission: Research, manifested at the THGFA in particular - but not exclusively - by the Research Centre for Post-Mining
- Third mission: transfer to society

In contrast, a technically and scientifically orientated association such as the vfdb sets the topics through its "guideline competence", with which the state of research and development for practical application is written down in the form of guidelines, leaflets and other elaborations via the Technical and Scientific Advisory Board (TWB). There are many publications on this in the association's own vfdb magazine, particularly emphasized in the brochure "Research at the vfdb" (vfdb 2022).

The lobby organization VdF NRW is moving in a very similar direction in the federal state of NRW. With leaflets and technical recommendations, as well as publications in the association's magazine FEUERWEHR.einsatz:nrw, it provides guidance on the implementation of research findings, albeit at a different technical level than the vfdb e.V.. This step became even more concrete with the establishment of the Research Expert Committee in June 2020 (Bernsdorf et al. 2021).

Status quo in the Competence Network for Security Research

A ranking list of the urgent topics on which research should be carried out could be derived from all recently published technical recommendations, guidelines and information sheets. It is also possible to see which topics have been dealt with from a research perspective and only need to be implemented. In 2019, the research working group of the AGBF NRW published the research needs after surveying its members (AGBF NRW 2019).

The KN SiFo can provide support here, as will be shown below. This is because the interests of the member organizations clearly show which current topics the member organizations are interested in. These are assigned to the following types of organization:

- Public authorities - both research and funding organizations
- Fire services and aid organizations - both interested and researching and applying units
- Research organizations - universities, Leibnitz, Max Planck, Fraunhofer, DLR institutes, etc.
- Associations - both interested and researching organizations as well as organizations representing users
- Companies - research departments but also SMEs looking for partners

All of them together are characterized by the fact that they form a good cross-section of the protagonists of security research. As the following statistics show, the network primarily addresses organizations that are active in "research". Here, the network needs to focus more on a more even distribution.

Member organizations

In the evaluation after the first year of activity on 24.05.2023, the competence network had 44 member organizations. These are distributed as follows:

- 2 authorities (5 %)
- 5 fire services and aid organizations (11%)

- 18 research institutions and universities (41%)
- 6 associations (14 %)
- 13 companies (30 %)

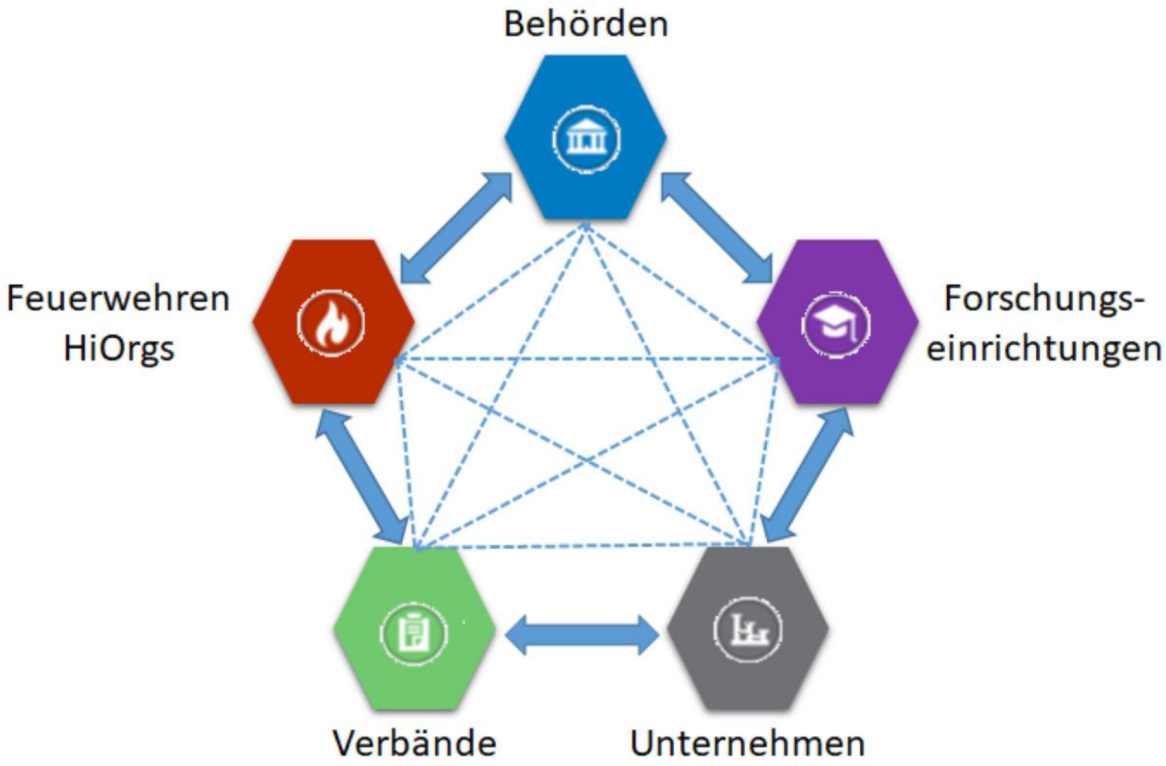


Figure 2: The network idea: finding partner organizations to promote joint research, facilitate exchange or make high-quality research results visible (source: Bernsdorf 2022)

Spatial Distribution

The geographical focus of the member organizations is still in North Rhine-Westphalia, but an increasingly nationwide distribution is becoming apparent. Organizations are represented in Schleswig-Holstein, Hamburg, Lower Saxony, North Rhine-Westphalia, Hesse, Baden-Württemberg, Bavaria, Saxony, Saxony-Anhalt, Brandenburg and Berlin. With one partner each from Austria and France, the first protagonists from the European region have become members (Figure 3).

Topics of Interest

When registering in the network, organizations can select subject areas of interest. For technical reasons, these subject areas are initially predefined so that they can be easily filtered according to areas of interest. However, multiple entries are possible so that organizations can also be found via bordering subject areas during a search. For example, situation visualization also has a lot in common with geodata or drone technology. This also takes into account the interdisciplinary nature of many projects in the field of security research. This evaluation probably provides the most exciting insight into the network. In total, all member organizations selected a topic area of interest 361 times thanks to the option of multiple selection in the topic areas: 8.2 areas of interest per organization, which is a good indication of the interdisciplinarity and breadth required in security research projects.

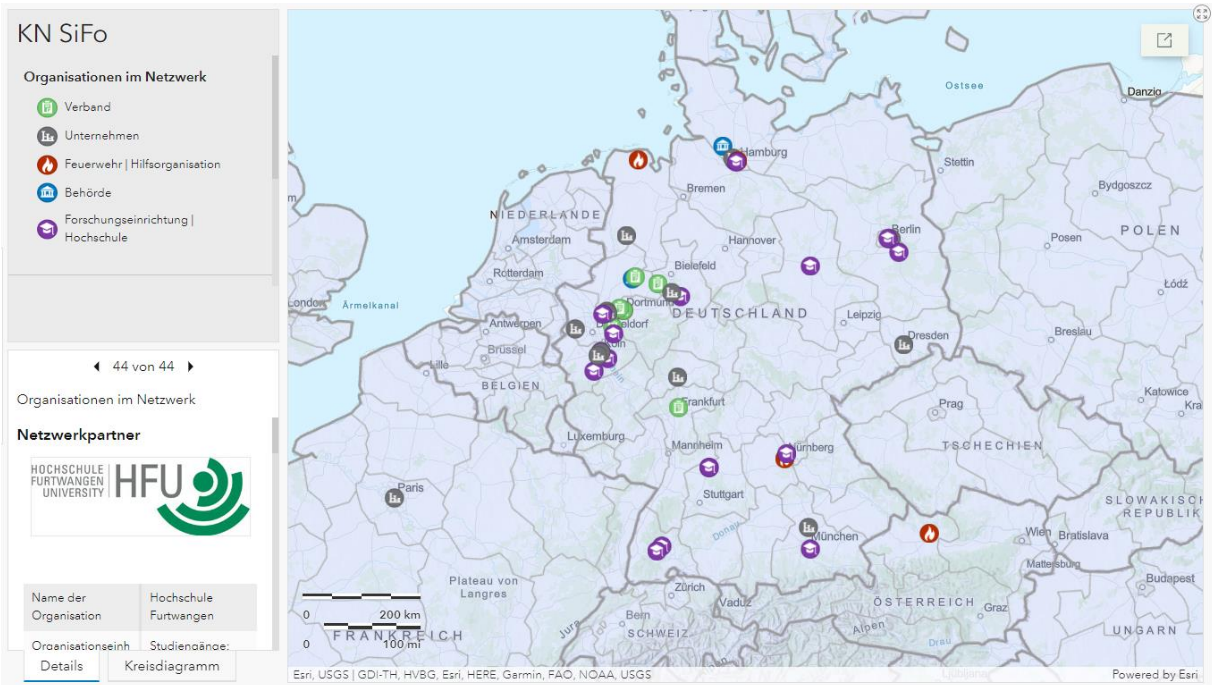


Figure 3: Spatial Distribution of network members (as at May, 24th 2023)

In particular, associations, research institutions, and universities, with their registered institutes, are often broadly diversified and necessarily do not only focus on a singular research field. Thus, an organization interested in risk, crisis, and disaster management may also be interested in geospatial data, staff work, and situation visualization. For example, a company operating in the virtual reality sector is also interested in market access and generally future-oriented research.

Figure 4 provides an overview of the distribution of interests, with interest in the more general topic area of risk, crisis and disaster management leading the way, with almost 65% of the participating organizations selecting it as being of high interest. This could be interpreted as a "self-fulfilling prophecy", as all organizations naturally work on this topic area to some extent. However, if one looks at the textual descriptions of the organizations, it becomes clear that only a few are actually active in this "management" environment, but rather pursue specific fields of work. Interpreted in both directions, however, it shows that in addition to classic fire protection or technical assistance, today it is also - or above all? - is about overarching issues in order to manage situations. This is understandable insofar as aid organizations, the THW and fire brigades are also increasingly having to deal with relevant issues of risk, crisis and disaster management. For example, a disaster management cycle (Figure 4) - such as the one on which the Copernicus Emergency Management Service is based (BBK n.d.) - includes risk analysis in the area of prevention and preparation as well as the reconstruction phase. It does not just cover incidents!

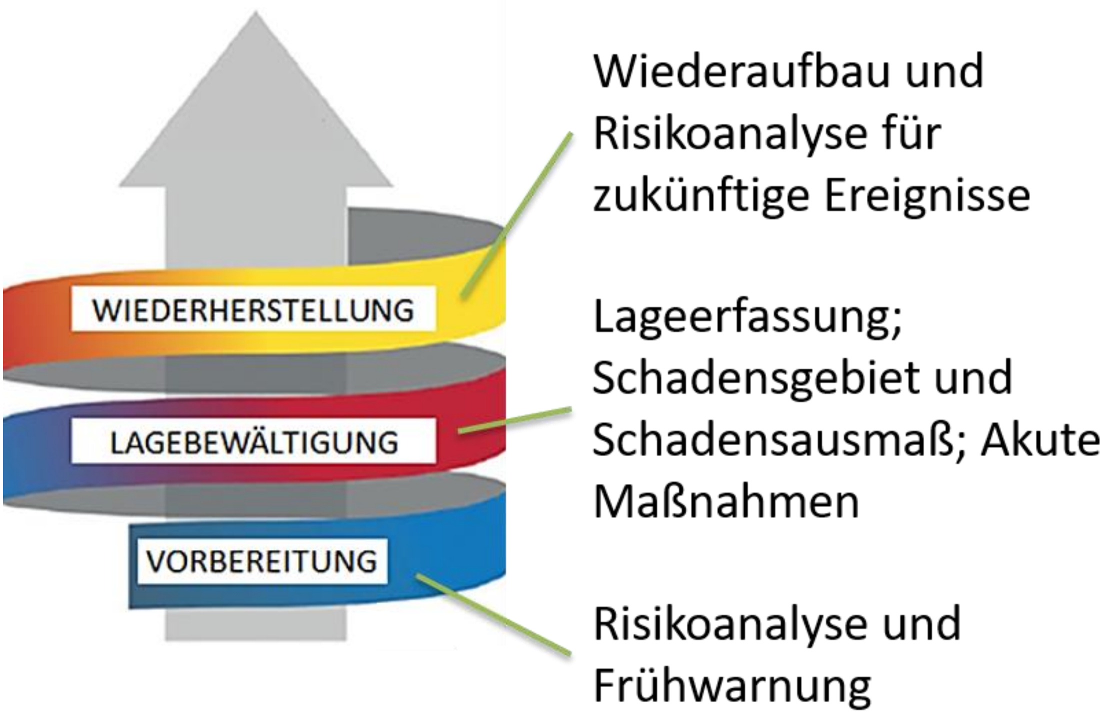


Figure 4: Example of a disaster management cycle; adapted from BBK o.J., modified.

The integration into such management systems has forced emergency services not only to become acquainted with the refugee wave of 2015 but also significantly during the just subsided COVID-19 pandemic. In general, emergency services are involved in prevention. Nevertheless, especially volunteer forces such as the volunteer fire brigades and the "white" aid organizations with their large number of personnel are primarily focused on the event itself, that is, the response. This is reflected, for example, in the provision of vehicles and equipment and is well documented, for example, by the fire protection needs planning. In order to change this situation and adapt it to the current requirements, disaster protection needs plans are being developed, especially in the states of North Rhine-Westphalia and Rhineland-Palatinate affected by the heavy rainfall disaster of 2021 (for example: IM NRW 2022, Chapter 3.3.2 Introduction of Disaster Protection Needs Planning, p. 16). These plans include all emergency services and especially the voluntary helpers, since organizations structured primarily by full-time staff, despite a high density - for example, in NRW - would quickly reach their limits of performance.

With each exceeding 50%, the areas of interest selected were Futures Research, Artificial Intelligence and Machine Learning, Geospatial Data and Monitoring, as well as Control Center Technology, Communication/Data, and Warning. Especially noteworthy from the author's perspective is the selection of the Futures Research topic, as currently only one member organization - the Fraunhofer Institute INT in Euskirchen - explicitly deals with the topic according to the organizational description. Here, the focus is indeed on examining research and development approaches regarding their future viability and potential market introduction. The high value of almost 57% suggests that practice-oriented research with future viability is still generally of interest to the participants.

A significant focus is on the field of AI and machine learning. Also, with almost 57%, it holds great importance. One of the future technologies, which will have significance especially in the context of the following two focal points: Geospatial Data/Geomatics Monitoring, and Control Center Technology, Communication/Data, and Warning (each just under 55%) regarding situation assessment. Because comprehensive geospatial data sets have been evaluated faster for years through machine learning, semantics, or neural networks than through manual processes (e.g., for Support Vector Machines: Graf & Wegenkittl 2012). The same applies in the future to other data, such as the evaluation of chats in social networks. A concrete application of AI (broadly interpreted here in terms of machine-assisted data analysis) can thus, for example, lead to better control center technology or earlier and more specific warnings to the population. It is worth mentioning that the data presented here were not influenced by the current AI discussion, but rather the network members made their choice before the publications on ChatGPT and the subsequent discussion about AI.

Turning now to the "top topics" in contrast to those chosen with less than 20% interest, it is noticeable that many "classic firefighting topics" are included here. Preventive fire protection, vehicle or general firefighting technology, clothing, and questions of respiratory protection obviously do not represent current research topics. One could interpret this as meaning that these topics are less attractive to researchers because they ultimately represent established state-of-the-art and provide little opportunity for researchers to engage. Although there are always new developments based on good considerations, observations, and new insights that are transferred from universities to practice (example Lenz Technology, Kloos 2022), the funding landscape is rarely ready to support research-related application development. A positive example is the funding measure "User - Innovative: Research for Civil Security II", which was announced on April 6, 2018. The focus of this announcement is on joint projects. In this context, the following are funded:

- innovative, application-oriented solutions that contribute to increasing the safety of citizens,
- project ideas focused on actual needs with the respective users at the center
- solutions based on a clearly civilian security scenario. (Source: BMBF 2018)

It should be noted that there is indeed a considerable need for research in the field of classic topics. Aspects such as psychosocial support or post-care, from the author's point of view, are far from comprehensive or satisfactory. The same applies to medical technology associated with fire and disaster protection and aspects of emergency medical services.

Between these two areas of great and lesser interest lies a broad middle ground of topics, some of which are surprising in their "placement". For example, the rapid development of UAV operations in the fire department or generally in the BOS would indeed be suitable to elevate aspects of drones and rescue robotics (46%) to a significantly higher level of interest. The same applies to staff work and situation visualization (39%) as a central component of a larger operation - especially in the context of major incidents and disasters, there are comprehensive questions to be solved here (Gißler et al. 2023; Gedicke et al. 2023). The heavy rainfall disaster in July 2021 clearly highlights weaknesses here. Looking at projects such as the Digital Situation Table (DigLT and DigLT-VR; van de Camp et al. 2020; IOSB n.d.[1,2]) of the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation (IOSB), there is still much to learn from developments for the Bundeswehr, and massive research is needed for the meaningful integration of such systems into an operator environment predominantly characterized by volunteers.

Wildfires (30%) and aspects of climate change, weather, and climate (27%) are also in the good midfield, but surprisingly already in the lower range for the author. Against the background that such aspects significantly influence the current operational situation, it can be assumed that these aspects will receive greater emphasis in security research in the future (for example: Cimolino & Velthaus 2023).

In many cases, such as medical technology, meteorological aspects, or robotics, it is assumed that their respective disciplines essentially conduct basic research. Weather and climate models themselves - to stick with one example - are therefore not necessarily the subject of security research. This research is carried out in meteorological institutes. However, security researchers can take up these basics and research findings and integrate them into the overall context. They can also identify knowledge and skill gaps for effective fire and disaster protection and a resilient society for the respective disciplines.

Figure 5: Interests of member organizations regarding the offered thematic areas

Conclusion and outlook

The Competence Network for Security Research has been active for a year as of May 2023. With the Days of Security Research and the subsequent publication of peer-reviewed articles, two of the goals outlined in the founding call are already being pursued in the current year. This is certainly a success, but both topics must be sustained if they are to be considered sustainable successes. Developing a congress event permanently and prosperously is quite a challenge considering the calendars of the protagonists, which are characterized by many events. The same applies to an open-access magazine with a high scientific standard. Both must be evaluated especially in light of the fact that there is no basic funding, and the network is only fueled by the engagement of the active participants.

Regarding the interests among the network organizations, it can be observed that significant future topics are shaping the research landscape. It has been demonstrated that classical topics in fire and disaster protection, in contrast, only generate limited interest among member organizations. One interpretation is that researchers adapt to the given conditions of funding programs, and applications focusing on future topics currently have a greater chance of success in the calls for proposals than focusing on detailed aspects in established environments. This may not always be beneficial because in fire and disaster protection, it is often the small details that bring about improvements in procedures. In the middle ground of interests, more complex topics are establishing themselves, where the suspicion arises that they are more reflected in the respective disciplines than in classical security research. This is plausible insofar as funding programs designed for security research do not or only implicitly consider such aspects. In contrast, there are again the classic (basic) research funding programs, which do not explicitly list security research as an applied and interdisciplinary research area. This was demonstrated using the example of the DFG subject committees. Here, there is a funding gap between basic research in classical disciplines and the applied and integrated application of such basics in the context of security applications.

Association work can help to better illustrate and gradually close this gap to funding agencies (cf. position paper InCluSiF et al. 2022). Because there is the impression that research on the application and integration of basic results from the disciplines is understood by funding institutions more as development or implementation than as research. However, since they are only transferable 1:1 in exceptional cases, there is indeed a need for research to be able to transfer the applications to practice.

Regarding the development in the Competence Network for Security Research, the expansion of participants will lead to further networking and a stronger base. At the time of writing the article (July 2023), the network already had 47 member organizations, thus recording a slower but continuous growth. This allows activities to be distributed on a broader basis and tasks to be shared among more shoulders. The presentation of current research needs is high on the agenda, so that the participating associations can reach a broader research base through this. However, the focus should be on the platform idea for exchanging security researchers at further Days of Security Research and the establishment of an open-access online magazine of high scientific quality.

Acknowledgments

The author would like to express gratitude to the founding organizations VdF NRW e.V., vfdb e.V. AK Forschung der AGBF NRW, and the Research Center of Post-Mining at THGA. All organizations contribute to the success of the network. Special recognition goes to the commitment of VdF NRW, which, together with Messe Dortmund, enabled the organization of the first Days of Security Research at the 112Rescue fair in 2023. Particular thanks are due to the team at THGA, which is currently working on the technical requirements for the open-access conference proceedings for the Days of Security Research and the planned open-access magazine. Freely

Technische Hochschule Georg Agricola

accessible research results are of great importance for the advancement of a research field. Marie Freifrau von Ebner Eschenbach (1830 - 1916) is associated with the quote that knowledge is the only asset that increases when shared!

(https://1000-zitate.de/4642/Das-Wissen-ist-das-einzige-Gut.html)

Here, Dr. Yvonne Liebermann and Cinja Bösel should be mentioned as the editor who oversees the peer review process, while Mrs. Laura Klein, for example, taking care of the contact with the library system of THGA and the assignment of the necessary Document Object Identifiers (DOIs)

Literature

AGBF NRW - Arbeitsgemeinschaft der Berufsfeuerwehren Nordrhein-Westfalen (2019): *Bestandsaufnahme Forschungsbedarf. Ausarbeitung des Arbeitskreis Forschung in der AGBF NRW zu den bestehenden Forschungsbedarfen im Brand- und Katastrophenschutz*, https://www.dortmund.de/media/p/feuerwehr/institut_fuer_feuerwehr__und_rettungs-technologie/downloads_21/20190524_AGBF_AKFO_Bestandsaufnahme_ForschBedarf_4.0.pdf [19.07.2023].

BBK - Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (o.J.): Katastrophenmanagement ist ein Zyklus. Info-Seite des BBK, Bonn, https://www.bbk.bund.de/DE/Themen/Krisenmanagement/KMZirkel/KMZirkel.html [18.07.2023].

BMBF - Bundesministerium für Bildung und Forschung (o.J.a): Die Forschungslandkarte: "Security Research Map". Internetauftritt unter SiFo.de zur Vernetzung der Akteure in der Sicherheitsforschung, https://www.sifo.de/sifo/de/service/researchmap/researchmap_node.html [18.07.2023].

BMBF - Bundesministerium für Bildung und Forschung (o.J.b): Forschungsnetzwerk deutscher Anwender (ForAn). Internetauftritt des Netzwerks ForAn zur Vernetzung deutscher Anwender in der zivilen Sicherheitsforschung, https://www.thw-forschung.de/DE/Forschungsprojekte/ForAn/Home/home_node.html [18.07.2023].

BMBF - Bundesministerium für Bildung und Forschung (o.J.c): Pakt für Forschung und Innovation. https://www.bmbf.de/bmbf/de/forschung/das-wissenschaftssystem/pakt-fuer-forschung-und-innovation/pakt-fuer-forschung-und-innovation_node.html [zuletzt besucht: 19.07.2023].

BMBF - Bundesministerium für Bildung und Forschung (o.J.d): Forschen für die zivile Sicherheit. Startseite des Förderprogramms. https://www.sifo.de/sifo/de/programm/forschung-fuer-die-zivile-sicherheit.html [19.07.2023].

BMBF - Bundesministerium für Bildung und Forschung (2018): Bekanntmachung - Richtlinie zur Fördermaßnahme "Anwender - Innovativ: Forschung für die zivile Sicherheit II". Bundeanzeiger vom 27.04.2018. https://www.bmbf.de/bmbf/shareddocs/bekanntmachungen/de/2018/04/1702_bekanntmachung.html [19.07.2023].

Bernsdorf, Bodo, Tim Glanert, Dieter Hennecke, Vanessa Kogel & Mark Niemann (2021): Die Facharbeit nimmt Gestalt an, in: *FEUERWEHR.einsatz:nrw*, Verbandszeitschrift des Verbands der Feuerwehren Nordrhein-Westfalen (VdF NRW) (6-7), 58-65.

Bernsdorf, Bodo (2022): Das Kompetenznetzwerk Sicherheitsforschung eine ArcGIS Online Plattform zur Vernetzung der Hightech Forschung, in: Vereinigung zur Förderung des deutschen Brandschutzes e.V. (Hrsg.), *Tagungsband 68. Jahresfachtagung der Vereinigung zur Förderung des deutschen Brandschutzes e.V. 2022 in Würzburg*. VdS Schadenverhütung GmbH Verlag, 289 – 306.

Bernsdorf, Bodo (2022): Gemeinsam forschen für eine sichere Zukunft. Das Kompetenznetzwerk Sicherheitsforschung, in: *FEUERWEHR.einsatz:nrw*, Verbandszeitschrift des Verbands der Feuerwehren Nordrhein-Westfalen (VdF NRW) (10), 3 - 7.

Cimolino, Ulrich & Christian Velthausz (2023): Niederlande erwarten mehr und grössere Waldbrände, in: *FEUERWEHR.einsatz:nrw*, Verbandszeitschrift des Verbands der Feuerwehren Nordrhein-Westfalen (VdF NRW) (4), 27 - 31.

DFG -Deutsche Forschungsgemeinschaft (2023a): Jahresbericht 2022. Aufgaben und Ergebnisse, https://www.dfg_jb2022.pdf [19.07.2023].

DFG - Deutsche Forschungsgemeinschaft (2023b): Fachsystematik Stand: 21. Juni 2023, https://www.dfg.de/dfg_profil/gremien/fachkollegien/faecher/ [19.07.2023].

FFG - Österreichische Forschungsförderungsgesellschaft mbH (o.J.): KIRAS- Sicherheitsforschung. Homepage des österreichischen Förderprogramms KIRAS- Sicherheitsforschung mit SecurityReserachMap. https://www.kiras.at/home [19.07.2023].

Graf, Roland J. & Stefan Wegenkittl (2012): Integration von Support Vector Machines in die objektbasierte Bildklassifizierung am Beispiel der Entwicklung eines Plug-Ins für eCognition, in: Josef Strobel, Thomas Blaschke & Gerald Griesebner (Hrsg.), *Angewandte Geoinformatik 2012. Beiträge zum 24. AGIT-Symposium Salzburg*. Berlin, Offenbach: Wichmann, 52–61, https://www.researchgate.net/publication/262698139_Integration_von_Support_Vector_Machines_in_die_objektbasierte_Bildklassifizierung_am_Beispiel_der_Entwicklung_eines_Plug-Ins_fur_eCognition#fullTextFileContent [19.07.2023].

Brauner, Florian (2016): Der kontinuierliche Veränderungsprozess der Sicherheitsforschung. Erfolgsfaktoren einer "guten zivilen Sicherheitsforschung", in: Gabel, Friedrich, Judith Eckert, Patrick Drews & Jan Hieronymus (Hrsg.), *Ergebnisbericht zum zweiten Workshop des Graduierten-Netzwerks "Zivile Sicherheit" zum Thema: "Was ist gute zivile Sicherheitsforschung?" vom 25./26. November 2016 in Stuttgart*, 55-57, https://www.researchgate.net/publication/315740660_Der_kontinuierliche_Veranderungsprozess_der_Sicherheitsforschung_-_Erfolgsfaktoren_einer_guten_zivilen_Sicherheitsforschung [18.07.2023].

Gedicke, Sven, Lukas Arzoumanidis & Jan-Henrik Haunert (2023): Automating the External Placement of Symbols for Point Features in Situation Maps for Emergency Response, in: *Cartography and Geographic Information Science* 50 (4), 385–402. https://doi.org/10.1080/15230406.2023.2213446.

Gißler, Dominik, Julian Gonschorek, & Lennart Landsberg (2023): Experimentalreihe: Die Stabsarbeit im Labor, in: Vereinigung zur Förderung des deutschen Brandschutzes e.V. (Hrsg.) *Tagungsband 69. Jahresfachtagung der Vereinigung zur Förderung des deutschen Brandschutzes e.V. 2023 in Münster*. VdS Schadenverhütung GmbH Verlag, 301-308.

IOSB – Fraunhofer Institut für Optronik, Systemtechnik und Bildauswertung (o.J.a). Digitaler Lagetisch – Beschreibung des Produkts. https://www.iosb.fraunhofer.de/de/projekte-produkte/digitaler-lagetisch.html [19.07.2023].

IOSB – Fraunhofer Institut für Optronik, Systemtechnik und Bildauswertung (o.J.b). Digitaler Lagetisch in der virtuellen Realität – Beschreibung des Produkts. https://www.iosb.fraunhofer.de/de/projekte-produkte/digitaler-lagetisch-virtuelle-realitaet.html [19.07.2023].

IM NRW – Ministerium des Innern des Landes Nordrhein-Westfalen (2022): Katastrophenschutz der Zukunft – Abschlussbericht des vom Ministerium des Innern berufenen Kompetenzteams Katastrophenschutz, https://www.im.nrw/system/files/media/document/file/berkompetenzteam2_0.pdf [19.07. 2023].

InCluSiF - Innovationsclusters Zivile Sicherheitsforschung, vfdb – Vereinigung zur Förderung des Deutschen Brandschutzes, AK FO A´GBF NRW - Arbeitskreis Forschung der Arbeitsgemeinschaft der Leiter der Berufsfeuerwehren in Nordrhein-Westfalen & DFG - Deutscher Feuerwehrverbband (2022): *Gemeinsames Positionspapier für den Agendaprozess zur Fortschreibung des Förderrahmens "Forschen für die zivile Sicherheit"*, https://www.vfdb.de/media/doc/positionspapiere/Gemeinsames_Positionspapier_InCluSiF_vfdb_AK_Forschung_DFV.pdf [19.07.2023].

Kloos, Svenja (2022): Vom Erfinder zum Unternehmer: GründungsServiceCenter StartING@THGA führt ersten Studenten zu erfolgreicher Gründung, https://www.thga.de/hochschule/neuigkeiten/meldung/vom-erfinder-zum-unternehmer-gruendungsservicecenter-startingthga-fuehrt-ersten-studenten-zu-erfolgreicher-gruendung [: 19.07.2023].

Porter, Michael (2000): Location, Competition and Economic Development: Local Clusters in a Global Economy, in: *Economic Development Quarterly* 14 (1) 15–34.

SERERN 5 Project (o.J.). Security Research Map. Karte und Datenbank des international aufgestellten SEREN 5-Projekts im Horizon Europe-Umfeld. https://www.security-research-map.eu//index.php?file=start_uk.htm [19.07.2023].

THGA - Technische Hochschule Georg Agricola (o.J.). Gesellschaftliches Engagement der THGA. Informationen zu dem Hochschul "Missionen". https://www.thga.de/transfer/gesellschaftliches-engagement/gesellschaftliches-engagement-der-thga [19.07.2023].

Van de Camp, Florian, Adrian Hoppe, Gabriel Unmüßig & Elisabeth Peinsipp-Byma (2020): Cooperative and Location-Independent Terrain Assessment for Deployment Planning Using a 3D Mixed Reality Environment , in: *Proceedings of SPIE 11426, Virtual, Augmented, and Mixed Reality (XR) Technology for Multi-Domain Operations* 1142604, https://doi.org/10.1117/12.2558593 [19.07.2023].

vfdb - Vereinigung zur Förderung des Deutschen Brandschutzes (Hrsg.) (2022, Juni): *Forschung bei der vfdb – Zusammenstellung der Artikelserie "Feuerwehr forscht"*, Sonderheft der Zeitschrift für Forschung, Technik und Management im Brandschutz, https://www.vfdb.de/media/doc/zeitschrift/Sonderheft_Forschung_2022.pdf [19.07.2023].

Link to presentation

https://thga.sciebo.de/s/zLiZf1evwCf8Y99

Fostering Faster and Better Change: A Proposal for Harnessing Continuous Improvement Processing (CIP) in Emergency Response Organizations

Jan Seitz

Technische Hochschule Wildau Technical University of Applied Science

Abstract

Emergency response organizations face significant challenges in adapting to constant changes. The concept of Continuous Improvement Process (CIP), well-known and highly relevant in the business sector, could be applied to address these challenges as it is specifically tailored for the gradual and continuous improvement of processes and workflows. However, its systematic application within the context of emergency response organizations is largely new and unexplored. This article proposes a conceptual five-phase model called "Continuous Improvement Process for Emergency Organizations" (CIP-ERO), based on the fundamental principles of CIP. The proposed model covers all stages of CIP, from process and system analysis to the final monitoring and evaluation of implementation success. Each phase is accompanied by specific methods, instruments, and challenges Building on this, it is argued that a successfully implemented CIP-ERO could yield various benefits, such as increased efficiency. The article provides an initial indication for discussion and encourages interested parties to collaborate in implementing and validating the concept in practice.

Preface

Emergency response organizations constitute a vital pillar of modern society. Their ability to reliably safeguard lives and values in the face of unforeseeable, occasionally catastrophic circumstances is a fundamental requirement for maintaining a high level of societal security. Additionally, these organizations also play an important 'socio-structural' role due to the German peculiarity of sometimes considerable voluntary commitment. This dual role elevates them to actors of significant importance, albeit ones who are, in a way, victims of their own success and consequently face increased challenges. The trends in types and frequencies of emergencies (e.g., the number of emergency rescues from 2000-2020; German Firefighters Association 2022) as well as numerous (sometimes anecdotal) reports and corresponding initiatives indicate a gradual decline in the general population's ability for self-protection and self-help (Federal Office of Civil Protection and Disaster Assistance 2006, 2011 & 2020; Goersch & Werner 2011; Kietzmann et al. 2015: 10-14; ADAC 2021; Voss 2021; German Association of Cities 2022). This trend can be attributed, at least in part, to the highly efficient emergency assistance system, increasing the pressure on emergency response organizations.

Simultaneously, the world has been undergoing rapid transformation for several years, marked by significant socio-technical changes. In addition to various megatrends such as Artificial Intelligence and Automation (Chui et al. 2018), Climate Change (Steffen et al. 2015), Demographic Shifts (United Nations 2019), and Migration and Urbanization (International Organization for Migration 2019), there is a need to address an evolving and increasingly complex threat landscape. The Federal Ministry of Education and Research have outlined this changing landscape in a funding guideline for 2023 by using terms like 'overlapping' and 'cascading' (Federal Ministry of Education and Research 2023). Against this backdrop, these organizations urgently need to evolve in response to the changing environment. This necessitates suitable instruments and approaches that can facilitate continuous adaptation to altered conditions and possibilities.

The need for adaptation, considered as 'quality,' extends far beyond emergency response organizations. In the business world, where adaptation is inherently ingrained in its DNA for long-term success, the concept of Continuous Improvement Process (CIP) is widely utilized. CIP is based on the principle of continuous improvement of processes through iterative loops, providing a structured framework for identifying, analyzing, and implementing incremental improvements. It corresponds to a dynamic perspective in which learning and adaptation are understood as integral components. Applied to emergency response organizations, CIP could enhance the effectiveness of interventions, operational efficiency, and overall readiness. However, the implementation of CIP within or by emergency response organizations is scarcely established and underexplored. This article aims to provide a conceptual contribution to understanding CIP as a potential instrument for the continuous adaptation of emergency response organizations by explaining how and under what conditions it can be implemented and what effects can be expected from it.

State of Art in Science and Technology

The concept of the Continuous Improvement Process (CIP) has its origins in business, particularly in quality management systems. Based on the preliminary work of Walter Andrew Shewhart (1939), Deming (1986) developed the Plan-Do-Check-Act cycle (PDCA) as a method for improving the quality and productivity of business processes. Changes are first planned (Plan), then implemented (Do), their success checked (Check) and, if necessary, readjusted (Act). This sequence is designed as a cycle so that the next cycle builds on the results of the previous one, thus enabling continuous improvement. Parallel to the PDCA cycle, another approach to continuous improvement developed in Japanese industry, Kaizen, which focuses on gradual improvements in which all employees are involved (Imai 1986). In contrast to the PDCA cycle, the focus is quite explicitly on small, continuous changes and less on larger, cyclical improvements; nevertheless, these small changes can certainly be part of larger improvement projects. While the PDCA cycle is primarily a management tool, Kaizen encourages employees to make suggestions for improvement and thus promotes a corporate culture that values proactive, continuous improvement (Brunet and New 2003: 1426-1446). However, both approaches share the core principle of the repetitive process of identifying, analyzing and implementing incremental improvements.

This principle is widely used in various business environments, and after initially focusing on manufacturing processes, it has also proven its worth in service industries and IT systems (Benner and Tushman 2003: 238-256). The practical effectiveness was soon reflected in international standardization: 'continuous improvement' is an elementary component of the ISO 9001 quality management system requirements and thus an indispensable basis for quality management systems worldwide; it is also required in numerous management system standards (e.g. ISO 22301 Business Continuity Management) in relation to the respective management system, which must of course also 'keep up with the times'. Outside of traditional management systems, CIP is often placed in the context of lean management (Womack and Jones 1996), Six Sigma (Pyzdek and Keller 2009) and Lean Six Sigma as a combination of both approaches (George 2003), methods that aim to reduce waste and increase efficiency. The basic idea of continuous improvement has also found its way into capability and maturity models, such as the Capability Maturity Model (Chrissis, Konrad and Shrum 2003) or the Organizational Resilience Maturity Model (UN System Chief Executives Board for Coordination). In parallel and in addition to these implementations, the CIP is often implicitly or explicitly implemented as a sub-element of change management (see e.g. Kotter 1996, Roth and DiBella 2015), whereby in this combination the CIP is used for rather minor adjustments, while change management 'orchestrates the overall picture'.

Furthermore, Continuous Improvement Process (CIP) is closely linked to idea management since improvements often stem from the systematic implementation of previously recorded ideas (Tidd and Bessant 2009). Additionally, effective knowledge management supports CIP by ensuring that insights and learning experiences are systematically captured, organized, and made accessible for future problem-solving and innovations. Conversely, CIP can provide valuable information for knowledge management initiatives (Nonaka and Takeuchi 1995).

To conduct or support a Continuous Improvement Process (CIP), dedicated CIP teams are often employed. These teams should ideally be interdisciplinary and cross-functional (Juran and Godfrey, 1999); Deming (1986) emphasized that quality is a concern that spans across organizations. Accordingly, team structure, composition, leadership (Bessant and Caffyn 1997: 7-28), and the facilitation of challenges (such as rivalries between departments; Schonberger 2007: 403-419) are crucial for the effectiveness of the CIP team. Additionally, Bateman (2005: 261-276) demonstrated that effective collaboration in teams increases the quantity and quality of improvement measures.

The concept of continuous improvement and the underlying activities required for it – taking stock, recognizing and selecting action options, implementing changes, evaluating effectiveness, and learning from the results – have something inherently human and natural about them, reflecting in various activities (such as finding a way from point A to B or practicing specific skills) and in different forms (such as leadership cycles) are already practiced in emergency response organizations. Despite (or perhaps because of) this universal application, a Continuous Improvement Process (CIP) is not a rigid process but rather a specific (thinking) approach. Indeed, even the relevant ISO standards (especially ISO/TS 9002 Quality management systems - Guidelines for the application of ISO 9001:2015, alongside ISO 9001) expect a continuous improvement process but do not prescribe its elements or outcomes. In this context, it is essential to perceive CIP as an element and outcome of a particular organizational culture, where all employees understand the value of continuous improvement and commit to it (Schein 2010). It is a culture where mistakes and failures are not just tolerated but embraced as opportunities for learning and improvement (Edmondson 2018). It also requires a specific kind of patience and long-term thinking, embracing small, incremental changes (Liker 2004).

Despite the significant importance and proven effectiveness of a Continuous Improvement Process (CIP) in various industries (see, among others, Liker 2004; Harry and Schroeder 2000; Antony, Kumar, and Labib 2008: 482-493), its application in the context of emergency response organizations remains relatively unexplored. There is scarce literature addressing the translation of CIP principles into the practices of emergency response organizations, a field that largely relies on established routines and protocols (Comfort, Waugh, and Cigler 2012: 539-547) and could, in principle, benefit from CIP. There are exceptions: for example, McEntire and Myers (2004: 140-152) discuss the concept of continuous improvement in the context of disaster management, and Portugall and Fiebig (2012) assess the "Continuous Improvement Program" of the German Armed Forces. However, there is a lack of scholarly attention regarding how essential emergency response organizations, vital to our society's survival, can adapt and improve in response to rapidly changing internal and external factors.

This shortcoming does not appear to be solely a result of a lack of scientific consideration. Numerous (especially internal) reports indicate a need for improvement in the ability of various operational organizations to move with the times and/or remedy identified shortcomings. There are also explicit discussions of this issue, such as in the Green Paper "Major emergencies" by the Expert Commission on Heavy Rainfall, which was still unpublished at the time this article was completed (September 2023) and is jointly supported by vfdb e.V. and DFV. Furthermore, studies, interviews and discussions with operational and management staff repeatedly point to a lack of ability to change (for example, with reference to the widespread, negative error culture (e.g. Regener 2011: 660-663; Bartels 2015: 19; Zimmer et al. 2015: 201-206; Seidensticker 2018; Seidensticker 2019: 78-91; Ahn, Sommer and Pratzler-Wanczura 2019; Schmidt 2021: 233-242). There is therefore a need for action.

Conceptual Proposal for CIP in Emergency Response Organizations (CIP-ERO)

Against the background of its need for action and drawing inspiration from the successful implementation of Continuous Improvement Process (CIP) in the business sector, a "Continuous Improvement Process for Emergency Response Organizations" (CIPERO) should be developed and implemented. CIPERO builds upon the fundamental principles and success factors of CIP in the business realm while incorporating necessary differentiations to suit the unique context of emergency response organizations. Based on these premises, the following working definition of CIP-ERO is proposed:

A "*Continuous Improvement Process in Emergency Response Organizations" (CIP-ERO) aims at the continuous enhancement of performance and working conditions within emergency response organizations. It encompasses a wide range of potential improvements, spanning from minor adjustments to comprehensive transformations. CIP-ERO addresses both recognized necessities for action and prospective opportunities for development. It is perceived as a tool to facilitate the adaptation of emergency response organizations to evolving challenges. CIP-ERO is an integrative process and a holistic endeavor, promoting and demanding honest, transparent collaboration among team members. It fosters mutual respect and understanding among individuals working together towards a common goal."*

This working definition reflects the approach that modifications of any type and scale should first be dealt with conceptually within the CIP-ERO rather than dividing them – as commonly done in businesses – into smaller initiatives (Continuous Improvement Process, CIP) and larger endeavors (Change Management).

Many challenges in emergency response organizations can be addressed with relatively small measures, or at least these measures can bring the solution one step closer. For example, a fire department is unlikely to suddenly implement widespread use of Artificial Intelligence (AI) and completely transform all processes and structures. Instead, they might gradually implement smaller initiatives along a (rough?) 'vision of an AI-assisted fire department,' taking incremental steps to both explore entirely new approaches and make changes to established solutions (e.g., progressively enhancing Personal Protective Equipment within the capabilities of 'smarter' technology). In a business context, the adoption of AI applications might be broadly promoted, anchored in change management processes, implemented locally through Continuous Improvement Process (CIP), informed by case studies, and supported by consulting services. Any temporary performance issues arising from process changes might incur costs but generally would not jeopardize lives. However, the situation in emergency response organizations is different, which is why it makes sense to approach this challenge with a unified methodology that maintains close contact with practical requirements (see below).

As outlined above, Continuous Improvement Process (CIP) in businesses is by no means rigid and is influenced by individual goals and resources. Therefore, a seamless transfer to emergency response organizations is not possible in and of itself. Consequently, Continuous Improvement Process for Emergency Response Organizations (CIPERO) must be conceptualized first, then implemented and evaluated in practice. This is an iterative process where feedback from real-world application can and must contribute to optimization. The first step in this process necessarily involves a pilot run based on predetermined conditions. For this purpose, the following initial version of a Continuous Improvement Process for Emergency Response Organizations is proposed, comprising several consecutive phases that continually repeat in their entirety (refer to figure 1):

The initial phase of CIPERO involves a detailed analysis of processes or systems, aiming to comprehensively understand the current organizational dynamics. The subsequent phase focuses on identifying improvement needs and opportunities, with the aim of recognizing both critical deficiencies and potential efficiency enhancements. The following phase refines and prioritizes these identified needs and opportunities into specific improvement objectives. Subsequently, the planned improvements are implemented in the execution phase, followed by monitoring and evaluation. This evaluation serves as the basis for another iteration of CIPERO under new conditions. True continuous improvement is only achievable through the ongoing courage to initiate new cycles of CIPERO based on evaluations. Each of the five phases requires specific methods and tools, which will be detailed further below.

The process and system analysis aims to establish a solid foundation for identifying optimization opportunities. This involves providing a detailed representation of processes using established methods such as flowcharts, time analyses, SIPOC diagrams (Suppliers, Inputs, Processes, Outputs, Customers), as well as failure mode and effects analysis. These methods ensure clarity and comprehensibility for the users.

It is essential to differentiate clearly between the tasks to be performed, the underlying necessity, and the resources – such as technical equipment, information, or skills – that are essential for the successful execution of the process. The integration of the process into the overall picture of the organization must also be clearly understood. For example, in the case of a maintenance process, it means analyzing when and why maintenance is necessary, what tasks need to be performed, what competencies and resources are required, and why this process is indispensable for the organization. This includes stakeholder analysis, examining who is affected, what interests these individuals or groups have, and how changes will affect them.

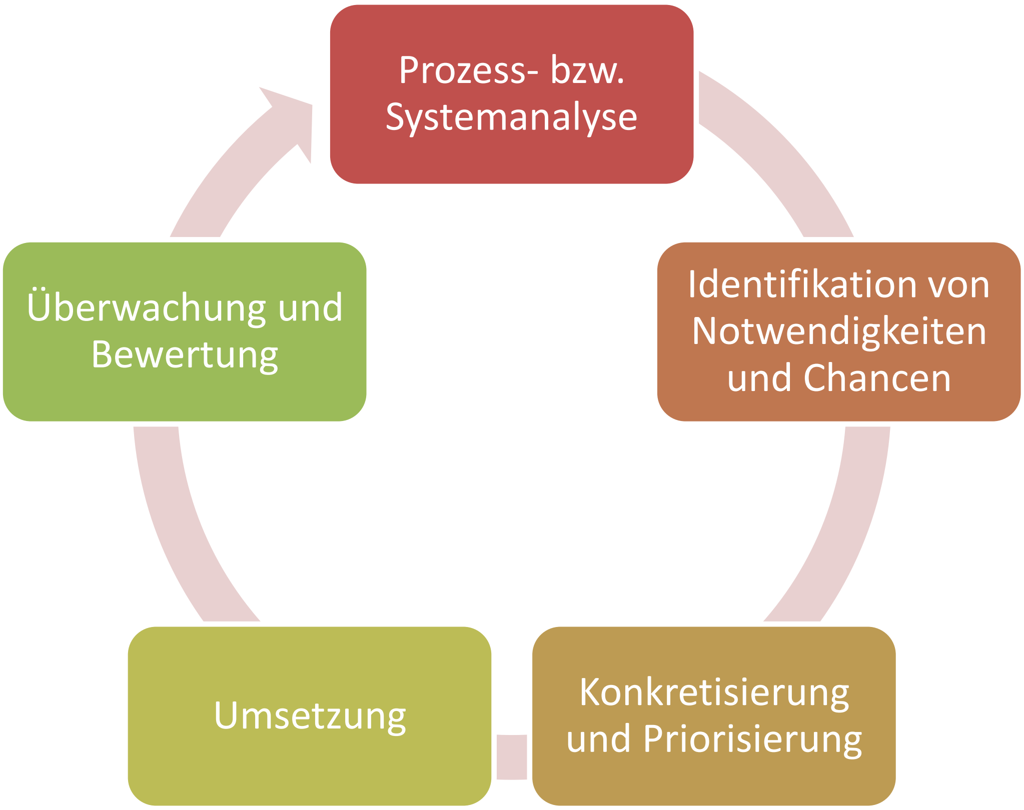


Figure 1: The five elements of the continuous improvement process for emergency response organizations. Own illustration.

A thorough understanding of the current conditions is crucial for redesigning a process. The complete and comprehensible documentation of the results is an integral part of the process and system analysis, supporting the transfer of insights to other organizations as well.

The subsequent identification of needs and opportunities draws on diverse sources such as feedback, error analyses, expert interviews, systemic reviews, or the availability of new solutions in the market. Needs ('what must be done') and opportunities ('what can be done') can take various forms, ranging from recognizing a technological catch-up demand to adjustments in (mission) planning fundamentals or changes in how emergency responders interact with each other. An example of a (widespread) 'need' would be the expanded incident evaluation: Improvement potentials in debriefings are often not fully captured, frequently due to a negative error culture or a debriefing process not aligned to address them.

The implementation of a structured feedback process and systematic documentation can address this issue, with the process remaining manageable and ensuring that the feedback is actually utilized. An example of an opportunity lies in the use of modern AI technologies, such as "Large Language Models" like ChatGPT. These models could make information much more quickly accessible, despite limitations such as the issue of hallucinations (i.e., the 'invention of facts'; Salvagno, Taccone, and Gerli 2023; Guerreiro et al. 2023).

It is crucial to clearly document and structure improvement opportunities to ensure transparency and comparability. This should be continuously updated and expanded through a suitable system (e.g., a database solution and documentation process). Aligning with existing norms and (de facto) standards, such as risk assessment, is sensible. It is also important to note that 'improvement' does not just mean adding or changing certain processes; it can also involve eliminating them. Similarly, in the process of concentrating competencies (e.g., regarding the use of drones by emergency organizations), one organization may take on tasks for another, or the interaction between them may change, which needs to be considered. In such cases, coordinating needs and opportunities with other stakeholders and possibly identifying them collaboratively can be beneficial.

Knowledge of the available options allows for the specification and prioritization of improvement opportunities, translating them into concrete goals and necessary steps for change. This process involves prioritizing based on effectiveness, feasibility, or other suitable criteria. Both current needs and future requirements should be considered, and in the case of interconnected or interdependent changes, roadmaps can be helpful. During this step, the feasibility, costs, and potential impacts of solutions should be analyzed. In addition to direct effects (e.g., impacts on response time), indirect effects should also be considered, such as a potential dependency on external service providers or an increased ability of emergency personnel to use modern technologies.

The analysis requires a constant weighing up of advantages and disadvantages, whereby different methods (e.g. Delphi method, utility value analysis, and simulation) can be used. Quantitative and qualitative methods should be used to avoid relying solely on 'hard facts' (which are uncertain when projecting into the future anyway) or on 'gut feeling' (which can be misleading). A clear 'vision' of the future operational organization can be helpful in navigating possible conflicting goals. (e.g. resilience vs. efficiency)

The prioritized approaches are then implemented, whereby the methodology may vary from project to project depending on the requirements (e.g. which people and processes are affected). Feedback from the previous phase may also be necessary, for example to adapt the implementation plan to unforeseen circumstances. Before practical implementation, clear criteria should be defined to determine when the desired goal has been achieved or when an implementation project should possibly be discontinued. During implementation processes, unexpected obstacles and side effects can arise that need to be addressed accordingly. The use of external expertise can be helpful here. During this entire phase at the latest, it is essential to always work with the (affected) people and involve them in the design of the CIPEO and the new processes, otherwise many projects will fail in later practical application due to a lack of acceptance, even if the implementation was successful per se.

During and after this phase, systematic monitoring and evaluation of the progress of the implementation is required, focusing on confirming the effective implementation of the planned changes and identifying success factors and obstacles. The evaluation is traditionally based on specific metrics, often known as Key Performance Indicators (KPIs), which can be both quantitative (based on usually extensive data sets; e.g. time between emergency call and arrival at the scene, duration of maintenance work) and qualitative (e.g. satisfaction or perceived stress in the field). This phase requires a high degree of transparency and honesty, because recognizing what has worked and what has not forms the basis for the next cycle of the CIPEO; this is where the foundation for a possible positive overall development is laid. It is therefore of central importance for the acceptance and effectiveness of the KVPEO in and for the organization. This implies that failures must also be tolerated and viewed as learning opportunities, whereby successful learning and any resulting changes are taken up again in the various phases of a subsequent CIPEO cycle.

Due to the novelty of the approach in the given context, it is advisable, especially at the beginning, to collaborate with various stakeholders across various organizations. For instance, forming a steering group can support the concretization of necessary steps, the development of templates, and the evaluation of results. This group should comprise representatives from different organizations, including academia, to broaden perspectives and enhance the chances of successful implementation. Additionally, this collaborative approach fosters learning at a meta-level, which can contribute to widespread adoption.

If the CIP is successful (with or without a network), numerous added values can be realized, such as

1. Improved efficiency and effectiveness: faster, safer and more resource-efficient operations through process optimization. In principle, optimization according to various criteria is also possible and appropriate outside of costs (e.g. according to resilience).

2. Increased satisfaction of emergency personnel: improved involvement of emergency personnel in process design, resulting in increased experience of self-efficacy, which can increase satisfaction and motivation, strengthen loyalty to the organization and have a positive impact on physical and mental health.

3. Promotion of innovation: establishing a culture of continuous improvement (with continuous learning as a central element) can lead to faster identification and implementation of new ideas and approaches, which in turn strengthens the organization's ability to innovate (and thus also to change).

4. Improved safety: regular review and improvement of processes and procedures can increase the level of safety for emergency personnel and those affected.

5. Improved risk management: early detection and minimization of risks through regular review and adaptation of processes, thereby avoiding potential problems and providing greater scope for action to proactively respond to changes and challenges.

Discussion

The process flow outlined here for a Continuous Improvement Process in Emergency Response Organizations (CIP-ERO) provides an initial point of orientation by identifying essential activities that are conducive to targeted, continuous improvement that goes beyond mere 'lessons learned'. The successful implementation of this cycle promises numerous benefits, for example in terms of the safety and satisfaction of emergency personnel. Another advantage is that the CIP-ERO can be used universally, regardless of whether training, exercises, operations or organization are being considered; although the people involved and the issues considered may change, the basic principles and the general process remain identical. As a next step, the CIP ERO described here in theory should be tested in a field study in various emergency organizations and analyzed to determine whether, how and, if so, under what special conditions the positive effects of a CIP known from the business world can also be realized by means of a CIP-ERO in the emergency organizations.

Evaluating the effectiveness of a KVPEO is both a research and implementation task, as there are still numerous unanswered questions as well as known, but hardly practiced approaches. It would certainly be appropriate to take the German Bundeswehr and its continuous improvement program as a model, for example with regard to the success factors and obstacles identified there. Nevertheless, the Bundeswehr is not a 'typical' operational organization and to some extent follows its own laws and logics of action, so that a suitable field study should also take into account the other 'worlds' (e.g. the fire department). Furthermore, the opportunity should be taken to carry out such an evaluation in the context of a dedicated research project, if possible, in order to establish a concrete framework with corresponding responsibilities and the necessary funding.

The question of funding is important, but ultimately not decisive: German operational organizations must become better at moving with the times. If the will is there, then the way will be found. Who like to go it?

Literature

ADAC (2021): ADAC Umfrage: Große Wissenslücken bei Erster Hilfe, https://www.adac.de/gesundheit/gesund-unterwegs/strasse/umfrage-erste-hilfe-kurs/ [06.06.2023].

Ahn, David, Katrin Sommer & Sylvia Pratzler-Wanczura (2019): *ATHEBOS Schlussbericht, Teilvorhaben: Initiierung der Fehlerkultur auf der technisch-taktischen Ebene*, https://www.tib.eu/de/suchen/id/TIBKAT:1699292965/ [15.09.2023].

Antony, Jiju, Maneesh Kumar & Ashraf Labib (2008): Gearing Six Sigma into UK Manufacturing SMEs: Results from a Pilot Study, in: *Journal of the Operational Research Society* 59 (4), 482-493.

Bartels, Hans-Peter (2015): Lessons Learned?, in: *Katholische Militärseelsorge – Kompass* 11/2015, 19.

Bateman, Nicola (2005): Sustainability: The Elusive Element of Process Improvement, in: *International Journal of Operations & Production Management* 25 (3), 261-276.

Benner, Mary J. & Michael L. Tushman (2003): Exploitation, Exploration, and Process Management: The Productivity Dilemma Revisited, in: *Academy of Management Review* 28 (2), 238-256.

Bessant, John & Sarah Caffyn (1997): High Involvement Innovation through Continuous Improvement, in: *International Journal of Technology Management* 14 (1), 7-28.

Brunet, Adam Paul & Steve New (2003): Kaizen in Japan: An Empirical Study, in: *International Journal of Operations & Production Management* 23 (12), 1426-1446.

Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (Hrsg.) (2006): *Dritter Gefahrenbericht der Schutzkommission beim Bundesminister des Innern. Bericht über mögliche Gefahren für die Bevölkerung bei Großkatastrophen und im Verteidigungsfall*, https://www.bbk.bund.de/SharedDocs/Downloads/DE/Mediathek/Publikationen/Forschung-und-Medizin/zf-band59-dritter-gefahrenbericht-sk.pdf?__blob=publicationFile&v=4 [16.05.2024].

Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (Hrsg.) (2011): *Vierter Gefahrenbericht*, Rheinbreitbach: MedienHaus Plump GmbH.

Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (Hrsg.) (2020): *Bevölkerungsschutz 2/2020. Selbstschutz und -hilfe*, https://www.maerkisch-oderland.de/datei/anzeigen/id/26899,1249/bsmag_2_20.pdf [16.05.2024].

Bundesministerium für Bildung und Forschung (2023): Richtlinie zur Förderung von Projekten zum Thema „Sicherstellung und Verbesserung der Handlungsfähigkeit von Staat und Verwaltung bei krisenhaften Ereignissen" im Rahmen des Programms „Forschung für die zivile Sicherheit 2018 – 2023" der Bundesregierung. Bundesanzeiger vom 14.03.2023. https://www.bmbf.de/bmbf/shareddocs/bekanntmachungen/de/2023/03/2023-03-14-Bekanntmachung-ZivileSicherheit.html [18.05.2023]

Chrissis, Mary Beth, Mike Konrad & Sandra Shrum (2003): *CMMI: Guidelines for Process Integration and Product Improvement*, Boston, MA: Addison-Wesley Professional.

Chui, Michael, James Manyika, Mehdi Miremadi, Nicolaus Henke, Rita Chung, Pieter Nel & Sankalp Malhotra (2018): *Notes from the AI Frontier: Insights from Hundreds of Use Cases*, McKinsey Global Institute.

Comfort, Louise K., William L. Waugh & Beverly A. Cigler (2012): Emergency Management Research and Practice in Public Administration: Emergence, Evolution, Expansion, and Future Directions, in: *Public Administration Review* 72 (4), 539-547.

Deming, William Edwards (1986): *Out of the Crisis*, Cambridge, MA: MIT Center for Advanced Engineering Study.

Deutscher Feuerwehrverband (2022): Statistik, https://www.feuerwehrverband.de/app/uploads/2022/12/221230_Statistik.pdf [20.05.2023].

Deutscher Städtetag (2022): *Bevölkerungsschutz bei unvorhergesehenen und außergewöhnlichen Ereignissen. Diskussionspapier des Deutschen Städtetages*, https://www.staedtetag.de/files/dst/docs/Publikationen/Positionspapiere/2022/diskussionspapier-bevoelkerungsschutz.pdf [29.11.2023].

Edmondson, Amy C (2018): *The Fearless Organization: Creating Psychological Safety in the Workplace for Learning, Innovation, and Growth*. Hoboken, NJ: Wiley.

George, Michael L. (2003) *Lean Six Sigma for Service: How to Use Lean Speed and Six Sigma Quality to Improve Services and Transactions*. New York, NY: McGraw-Hill.

Goersch, Henning G. und Ute Werner (2011): *Empirische Untersuchung der Realisierbarkeit von Maßnahmen zur Erhöhung der Selbstschutzfähigkeit der Bevölkerung*. Bonn: Bundesamt für Bevölkerungsschutz und Katastrophenhilfe.

Guerreiro, Nuno M., Duarte M. Alves, Jonas Waldendorf, Barry Haddow, Alexandra Birch, Pierre Colombo & André F. T. Martins (2023): *Hallucinations in Large Multilingual Translation Models*. arXiv:2303.16104 [cs.CL], https://arxiv.org/abs/2303.16104 [21.09.2023].

Harry, Mikel & Richard Schroeder (2000): *Six Sigma: The Breakthrough Management Strategy Revolutionizing the World's Top Corporations*. New York, NY: Currency/Doubleday.

Imai, Maasaki (1986): *Kaizen: The Key to Japan's Competitive Success*. New York, NY: Random House Business.

International Organization for Migration (2019): *World Migration Report 2020*, https://publications.iom.int/system/files/pdf/wmr_2020.pdf [29.11.2023].

Juran, Joseph M. & A. Blanton Godfrey (Hrsg.) (1999): *Juran's Quality Handbook*, New York, NY: McGraw-Hill.

Kietzmann, Diana, Daniela Knuth, Katharina Hegele & Silke Schmidt (2015): Notfallwissen in der Bevölkerung Deutschlands, in: *BBK Bevölkerungsschutz* 3/2015, 10-14.

Kotter, John P. (1996): *Leading Change*, Boston, MA: Harvard Business School Press.

Liker, Jeffrey K. (2004): *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*, New York, NY: McGraw-Hill.

McEntire, David A. & Amy Myers (2004): Preparing Communities for Disasters: Issues and Processes for Government Readiness, in: *Disaster Prevention and Management* 13 (2), 140-152.

Nonaka, Ikujiro & Hirotaka Takeuchi (1995): *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*, New York, NY: Oxford University Press.

Portugall, Gerd & Rüdiger Fiebig (2012): Das Kontinuierliche Verbesserungsprogramm (KVP) – Eine Zwischenbilanz aus organisationswissenschaftlicher Sicht, in: Richter, Gregor (Hrsg.). *Neuausrichtung der Bundeswehr. Beiträge zur professionellen Führung und Steuerung.* Wiesbaden: VS Verlag für Sozialwissenschaften, 133-152.

Pyzdek, Thomas & Paul Keller (2009): *The Six Sigma Handbook, Third Edition*, New York, NY: McGraw-Hill Education.

Regener, Helge (2011): Ein Fehler ist kein Fehler, zwei Fehler sind einer zuviel!, in: *Rettungsdienst* 7/2011, 660-663.

Roth, George L. & Anthony J. DiBella (2015): *Systemic Change Management*, New York, NY: Palgrave Macmillan.

Salvagno, Michele, Fabio Silvio Taccone & Alberto Giovanni Gerli (2023): Can Artificial Intelligence Help for Scientific Writing?, in: *Critical Care* 27, 75.

Schein, Edgar H. (2010): *Organizational Culture and Leadership*, San Francisco, CA: Jossey-Bass.

Schmidt, Kurt W. (2021): Der Umgang mit belastenden Ereignissen als organisationsethische Herausforderung am Beispiel „Behandlungsfehler“, in: *Ethik in der Medizin* 33 (2), 233-242.

Schonberger, Richard J. (2007): Japanese Production Management: An Evolution – with Mixed Success, in: *Journal of Operations Management* 25 (2), 403-419.

Seidensticker, Kai. (2018): *Zur Notwendigkeit von Polizeiforschung: Theorie und Praxis polizeilicher Fehlerkultur*, https://nbn-resolving.org/urn:nbn:de:0168-ssoar-58661-1 [21.09.2023].

Seidensticker, Kai. (2019): Fehlerkultur der Polizei. Die Wirkung von Organisationsstruktur und Männlichkeitskonstruktionen auf den Umgang mit Fehlern, in: *SIAK-Journal – Zeitschrift für Polizeiwissenschaft und polizeiliche Praxis* 3/2019, 78-91.

Shewhart, Walter A. (1939): *Statistical Method from the Viewpoint of Quality Control*, Mineoa, NY: Dover Publications.

Steffen, Will, Katherine Richardson, Joahn Rockström, Sarah E. Cornell, Ingo Fetzer, Elena M. Bennett, Reinette Biggs, Stephen R. Carpenter, Wim de Vries, Cynthia A. de Wit, Carl Folke, Dieter Gerten, Jens Heinke, Georgina M. Mace, Linn M. Perrson, Veerabhadran Ramanathan, Belinda Reyers & Sverker Sörlin (2015): Planetary Boundaries: Guiding Human Development on a Changing Planet, in: *Science* 347, 1259855.

Tidd, Joe & John Bessant (2009): *Managing Innovation: Integrating Technological, Market and Organizational Change*, Hoboken, NJ: John Wiley & Sons.

UN System Chief Executives Board for Coordination (o.J.): *UN Organizational Resilience Maturity Model*, https://unsceb.org/sites/default/files/2021-12/Approved%20Organizational%20Resilience%20Maturity%20Model.pdf [21.05.2023].

United Nations, Department of Economic and Social Affairs, Population Division (2019): World Population Prospects 2019, https://population.un.org/wpp/Publications/Files/WPP2019_10KeyFindings.pdf [16.05.2024].

Voss, Martin (2021): Stellungnahme: Zustand und Zukunft des Bevölkerungsschutzes in Deutschland – Vorschlag für ein „Forschungs- und Kompetenzzentrum Resilienz und Bevölkerungsschutz“, in: *Deutscher Bundestag, Ausschuss für Inneres und Heimat. Ausschussdrucksache* 19 (4), 793 E.

Womack, James P. & Daniel T. Jones (2003): *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*, New York, NY: Simon and Schuster.

Zimmer, Matthias, Rainer P. Waßmer, D. Oberndörfer, V. Wilken, Leo Latasch, Wilhelm Schier und Christian Byhahn (2015): Patientensicherheit im hessischen Rettungsdienst, in: *Notfall + Rettungsmedizin* 18 (3), 201–206.

Link to presentation

https://thga.sciebo.de/s/h03055OAcmfk4xY

Technische Hochschule Georg Agricola

Days of Security Research

Day 1: Juni 14th 2023

Session: Future Technologies Part 1

An algorithm for the automatic placement of tactical signs in the digital situational awareness sketch

Sven Gedicke, Lukas Arzoumanidis, Jan-Henrik Haunert

University Bonn

Note:

This article was originally published in the vfdb magazine "Die Zeitschrift" issue 2 2023 (72nd year), p. 59-65. We would like to thank the editors for making it available.

For this reason, the article was not subject to peer review for the conference proceedings, but was comprehensively checked by the vfdb editorial team for compliance with good scientific practice.

Abstract

A clear presentation of the situation is essential for targeted operational planning. Fire departments and disaster control services use situation sketches for this purpose. These contain relevant elements within a map overview, which are labeled with tactical symbols at the edge of the map. Despite existing digital solutions, the symbols are usually placed manually. This process takes up valuable time and human resources, which can be saved by automatic placement.

This article presents an algorithm that automatically places tactical signs at the edge of the map, taking into account intersection-free and short connecting lines, the relevance of the signs and a grouping of signs that are similar in content or spatially close.

Motivation

If emergency operations occur as a result of damaging events, situational awareness is a key aspect of the management organization of fire departments and disaster control. Particularly in complex situations, it is essential for the targeted management and coordination of the emergency services to be able to perceive and understand all relevant elements of the situation and to be able to assess their further development (Endsley, 1995).

Information on the situation is recorded and collected from the moment the incident is reported to the control center until the on-site reconnaissance. Existing geodata services complete the collection of information and enable additional information to be obtained, such as the locations of hydrants, pipe networks and access to properties and buildings (Bernsdorf and Fritze, 2016). Since a large number of different forces with different competencies and responsibilities usually work together, the usually extensive collection of information must be communicated in as organized a manner as possible.

With the aim of effective and structured command and control work, emergency services in North Rhine-Westphalia (NRW) therefore use a standardized situation display system developed at the Institute of the North Rhine-Westphalia Fire Service (Tdf) (Lamers and Denker, 2022).

The system comprises three different scales for different levels of command: the tactical worksheet for platoon leaders in the field, the tactical work board for unit leaders and the tactical work wall for staff work. Even though the three scales differ in terms of the scope of the information displayed, they all have one central element in common: the situation sketch. This is used to display the situation in the form of a rectangular map overview and thus in particular to display geodata relevant to the operation. Depending on the application, topographical maps, terrain models, aerial photographs or even floor plans can be used as background maps. Relevant elements within the map are labeled with tactile symbols at the edge of the map. The visual association of a symbol with the respective position on the map is established via a connecting line. An example of such an (electronic) location sketch is shown in Figure 1.

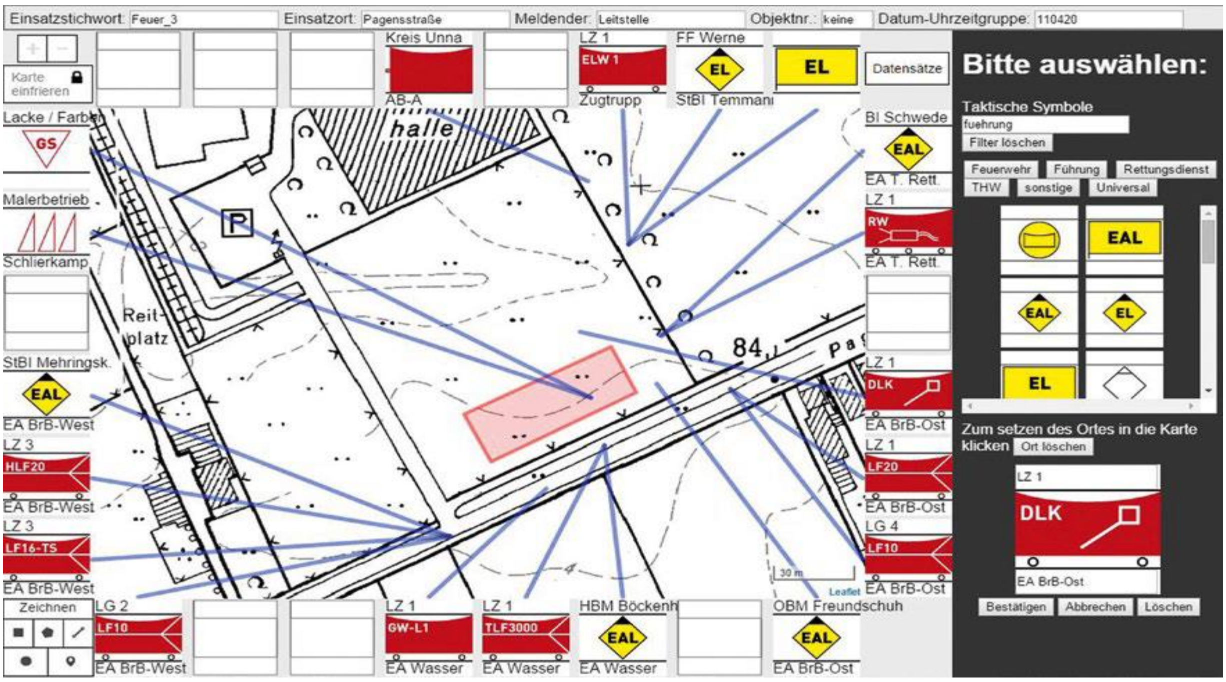


Fig. 1: Electronic version ofa situational awareness sketch, produced using Open-Source-Software LAGEskizze (Bernsdorf und Fritze, 2016).

In practice, analog location sketches in paper form are still often used. However, there is great potential in modern digital implementations, particularly with regard to flexible visualizations and interaction options. The authors are of the opinion that the use of digital location sketches not only saves natural resources, but can also increase efficiency in terms of creating situational awareness. In contrast to analog maps, the digital implementation allows for flexible panning and zooming of the map section as well as switching between different background maps (e.g. aerial photo and topographic map).

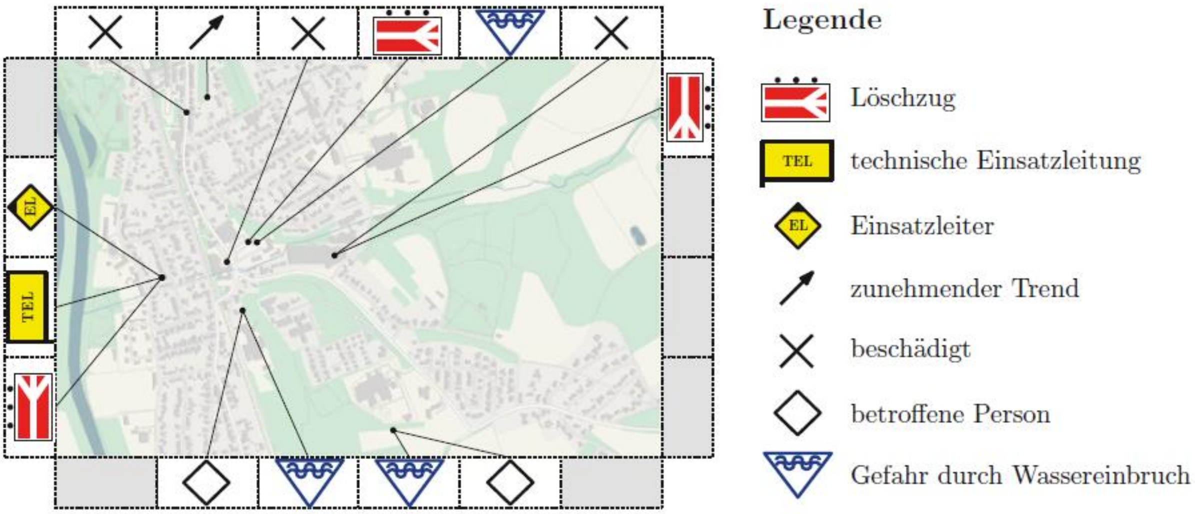


Fig. 2: Example of a digital sketch in which the tactical signs were placed using the algorithm presented in this article. The information shown is based on a real situation. The tactical signs were chosen according to the principles of the German Federal Agency for Technical Relief (THW). Map tiles from Carto, under CC BY 3.0. Map data from OpenStreet-Map, under ODbL.

Open source software has already been developed in recent years with the aim of digitally implementing the established NRW situation awareness system and, in particular, the situation sketch it contains (Bernsdorf and Fritze, 2016; Lamers and Fortkamp, 2019). After selecting and fixing a suitable map section, the positions of relevant elements can be marked on the map and corresponding tactical signs can be placed manually at the edge of the map. Even though the manual placement of tactical symbols allows a high degree of flexibility, this work step requires time and personnel resources that are particularly valuable in time-critical operations and could be saved.

In this context, this article argues that the automatic placement of tactical signs can both relieve the burden on the emergency services and save important deployment time. The article takes up this potential and presents an algorithm that automates the placement of tactical signs. The algorithm takes into account the tactical relevance of the signs, prevents crossing lines and minimizes the length of the lines. The algorithm also allows tactical signs to be grouped according to their semantic similarity or their position on the map. Grouped characters are placed next to each other. It is shown that the algorithm generates results in less than a second and is therefore suitable for interactive applications in deployments. Figure 2 shows an exemplary location sketch in which the tactical characters were placed by the algorithm.

In the following, the automatic placement of labels and symbols in maps is examined as a field of research. The example of the NRW location display system is taken up and the criteria for automatic character placement in location sketches are derived in this context. A mathematical model is set up and the algorithm is presented. In a subsequent discussion, the results of the algorithm are evaluated with regard to their computing time and the potential of automation is presented. Finally, a brief summary of the article follows.

Automatic signature placement in cartography

Providing maps with text labels, symbols and signs has been an important field of research in map visualization for many decades. The objects to be placed are often summarized under the term label. Labels not only convey information about the geographical objects they contain, but also improve the aesthetic appearance (Ahn and Freeman, 1983). In particular, the clarity and perceived complexity of a map depend on the positioning of the labels (Imhof, 1975; Liao et al., 2019). Since manual label placement is a very time-consuming task (Morrison, 1980), with the advent of digital maps, research has increasingly focused on the development of strategies for automatic placement (Yoeli, 1972; Ahn and Freeman, 1983; Hirsch, 1982).

Eine der gängigsten Strategien ist die Festlegung von Optimierungszielen und Nebenbedingunggen nach grundlegenden kartografischen Prinzipien und Richtlinien. Ein etablierter Ansatz dabei ist es, die Anzahl der visualisierten Labels bei gleichzeitigem Verbot von Überschneidungen zu maximieren. Diese Strategie wird auch als Suche nach einem maximum independent set (zu Deutsch maximale unabhängige Menge) bezeichnet (Agarwal et al., 1998). Um zusätzliche kartografische Gesichtspunkte zu berücksichtigen, werden den Labels häufig Gewichte zugewiesen, die bestimmte kartografische Eigenschaften quantifizieren. Ziel ist es dann, eine One of the most common strategies is to define optimization goals and constraints according to basic cartographic principles and guidelines. An established approach is to maximize the number of visualized labels while prohibiting overlaps. This strategy is also referred to as searching for a maximum independent set (Agarwal et al., 1998). In order to take additional cartographic aspects into account, labels are often assigned weights that quantify certain cartographic properties. The goal is then to find an overlap-free subset of labels that maximizes the sum of weights. In the literature, this approach is often referred to as maximum weighted independent set (Pardalos and Xue, 1994).

Even for simple scenarios where square labels of the same size are used and all labels are given the same weight, finding independent sets is a notoriously complex (a so-called NP-hard) problem (Fowler et al., 1981).

To solve such complex problems, combinatorial optimization methods are often used. The aim here is to find a solution from a discrete set of solutions that fulfills certain conditions and is optimal with regard to an objective function. Linear optimization is a widely used method to solve a problem exactly, i.e. to achieve an optimal solution (Haunert and Wolff, 2017; Marín and Pelegrín, 2018; Lamm et al., 2019). However, calculating an optimal solution often requires long computation times, which makes these approaches impractical for use in interactive applications. Therefore, many authors focus on heuristic approaches (Luboschik et al., 2008; Yamamoto et al., 2002; Cai et al., 2018). A heuristic is generally understood to be a procedure for solving a mathematical problem that provides a good approximate solution in a short time. This paper also presents a heuristic for automatic character placement in location sketches, which generates solutions in less than a second whose quality comes close to the optimal solutions in terms of the selected objective function.

In addition to exact and heuristic methods, there is a third category of methods: approximation algorithms (Gemsa et al., 2020; Mitchell, 2021; Chuzhoy and Ene, 2016). Similar to heuristics, these algorithms solve a given problem approximately, but guarantee a minimum quality of the solution.

Placement of tactical signs in an situational awareness sketch as Optimization Problem

In order to be able to automate the placement of tactical signs in situation sketches, clear optimization lines and conditions must first be defined. In order to best take into account the actual requirements of emergency services, the authors conducted expert surveys on the placement of signs in situation sketches. The surveys took place online and a total of seven experts from the fields of flood protection, disaster control, fire departments and cartography took part. Given a fictitious emergency scenario (severe weather with heavy rain and storms), the experts were asked to evaluate various statements on tactical signs and their positioning. The statements were based on the established layout of situation sketches as used in the NRW situation display system (see Figure 1).

With regard to the representation of the connecting lines between tactical signs and their positions on the map, the experts agreed that the lines must not cross each other for a clear association. Short connecting lines are also preferable for a clear presentation and to minimize coverage of the background map. Furthermore, the experts agreed that grouping tactical signs with similar or identical content (e.g. different danger signs) can contribute to a clear visualization. In addition to such semantic grouping, grouping according to the position on the map can also be helpful in order to quickly identify key areas of deployment.

If there is not enough space at the edge of the map to display all the characters contained in the map section, it may also make sense to place only the most relevant characters.

For this purpose, a mathematical model was created that generates a candidate for every combination of a possible character position at the edge of the map (hereinafter referred to as a slot) and an element to be labeled in the map section. The set of all candidate data thus corresponds to the set of all possible connecting lines. In the following, connection lines that are selected in a current solution are referred to as active and all unselected lines as inactive. To illustrate this, Figure 3 shows a schematic diagram with only one element to be labeled. With the ten slots available at the edge of the map, there are nine inactive candidates in the exemplary solution in addition to the one active candidate.

In summary, an optimization problem must be formulated that strictly prohibits crossing connection lines and optimizes the following criteria:

K(Prio)	prioritized presentation of relevant content
K(Length)	short connecting lines
K(Group)	grouping of characters with similar content or close spatial proximity

Based on this model, a set of active candidates is sought that leads to no crossings and that optimizes the criteria K(Prio), K(Length) and K(Group). The three criteria are modeled in an objective function to be maximized, which will not be discussed in detail here. The optimization problem set up is referred to in the following as a car location sketch.

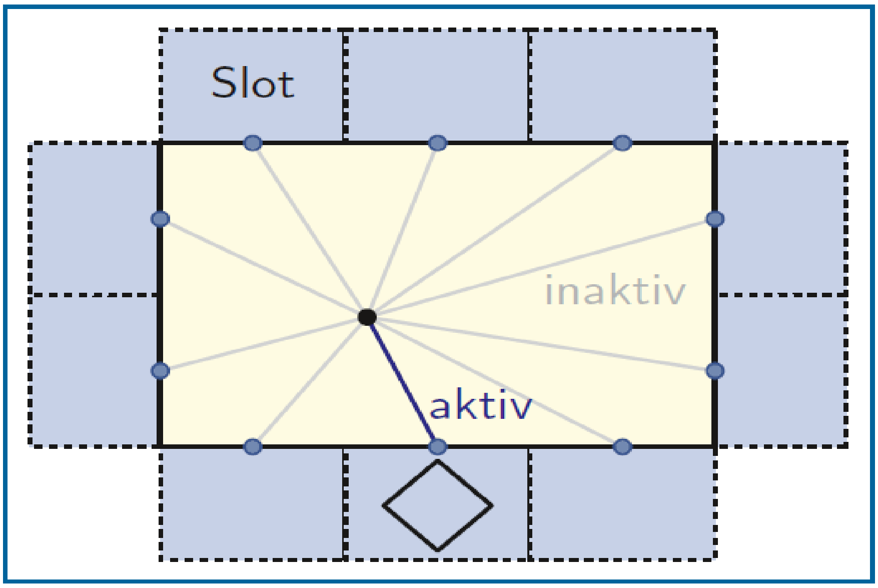


Figure 3: Schematic representation of a situational sketch with only one element to be labeled (black dot). The dark blue line represents the active candidate, the nine gray lines the inactive candidates.

Algorithm

The real-time capability of an algorithm is particularly essential for time-critical applications such as deployment planning in emergency situations. This also applies to the automatic placement of tactical signs in situation sketches. If emergency services have to wait several seconds or even minutes for a labeled map to be created, it is difficult to justify the automated process over the established manual approach. This paper therefore uses a heuristic method to solve the optimization problem of auto-position sketches, which achieves an approximate solution in a short time.

The heuristic is based on a strategy from the field of local search. Starting from an initial solution, the basic idea is to achieve a better solution by making local changes to the current solution. An important aspect of this is the definition of a so-called neighborhood. A neighborhood defines the set of solutions that can be achieved by a single local change. Each solution in the neighborhood is called a neighbor. The local search is an iterative procedure in which a new neighbor is considered in each iteration. The algorithm checks whether this new solution is better with regard to the selected objective function. If this is the case, the considered neighbor is accepted as the new solution. Such a procedure is also known as hill climbing. One problem with hill climbing, however, is that the procedure ends as soon as there is no more neighboring solution that brings about an improvement. However, such a local optimum does not necessarily correspond to the global optimum; see Figure 4.

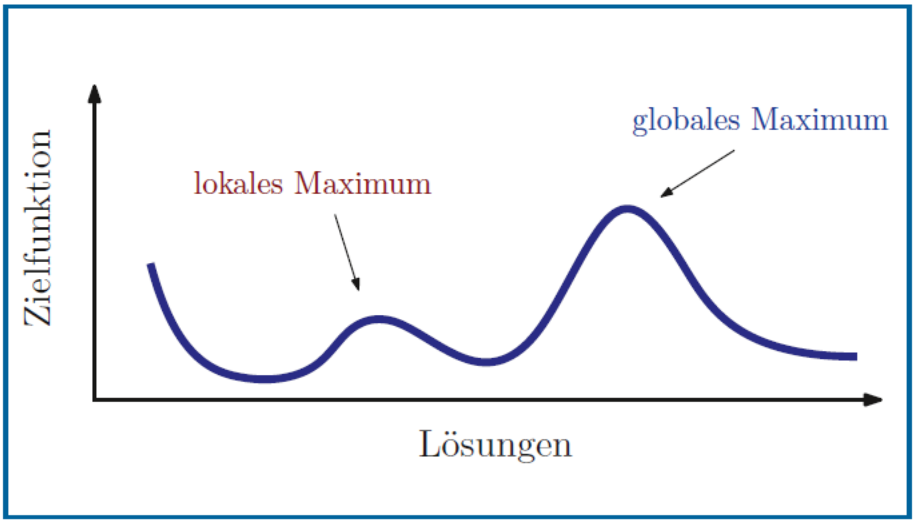


Figure 4: Schematic representation of local and global maxima.

An extended method, on which the algorithm presented here is based, is simulated annealing (Van Laarhoven and Aarts, 1987). So that local optima can be left during the iterative process, solutions with a lower quality are also accepted with a certain probability.

As the name suggests, Simulated Annealing is inspired by the cooling process of a material (e.g. a glowing metal). Analogous to the deformability of the material with decreasing temperature, the probability of accepting a poorer solution decreases with increasing number of iterations. The algorithm ends when a previously defined number of iterations is reached.

Specifically, in relation to the problem AutoLageskizze, the neighborhood of a solution is defined as the set of all solutions that can be reached by a swap. A swap initially describes the insertion of a previously inactive candidate into the current solution. All candidates that conflict with this candidate are moved to the set of inactive candidates. An example of a swap is shown in Figure 5. In a subsequent fill-up step, an attempt is made to fill unoccupied slots. To do this, as many inactive candidates as possible are moved into the set of active candidates in random order, without two active candidates intersecting. Whether the solution created after the swap is accepted depends on the quality of the target function and the probability in the current iteration.

Anwendung und Diskussion

Um den entwickelten Algorithmus anzuwenden und Ergebnisse beurteilen zu können, wurden 30 fiktive Lageskizze erzeugt. Es wurden für jeweils unterschiedliche Kartenbereiche Inhalte des freien Kartendienstes OpenStreetMap extrahiert, die die mit taktischen Zeichen zu beschriften-den Elementen repräsentieren (z.B Hydraten, Sammelstellen und Notausgänge). Zudem wurden von einem der Experten bereitgestellte Daten eines realen Einsatzes verwendet, aus denen der Algorithmus die in Abbildung 2 dargestellte Lageskizze erzeugt hat.

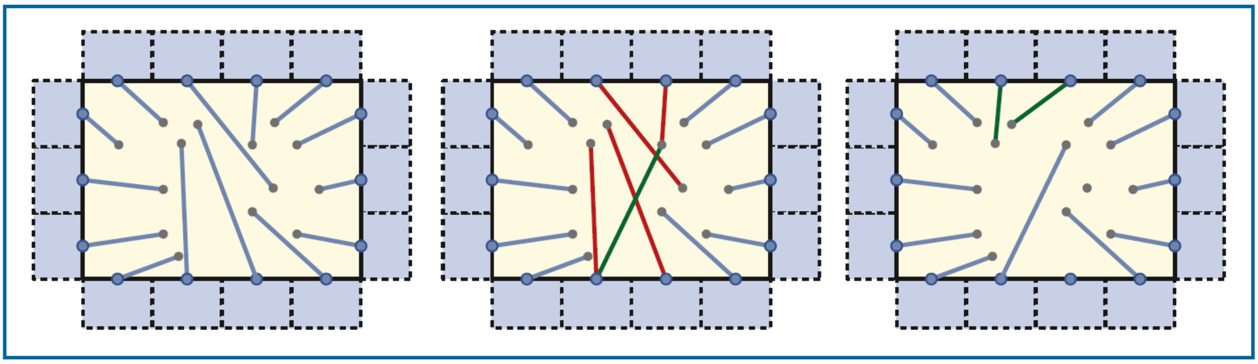


Abbildung 5: Schematische Darstellung eines Tausches. Die Lösung vor dem Tausch ist links dargestellt. In der mittleren Abbildung stellt die grüne Linie den Kandidaten dar, der in die Menge der aktiven Kandidaten eingefügt werden soll. Die roten Linien stehen in Konflikt mit diesem Kandidaten, und daher werden die zu den roten Linien gehörenden Kandidaten in die Menge der inaktiven Kandidaten verschoben. Rechts ist die Lösung nach dem Tausch dargestellt. Die grünen Linien zeigen die Kandidaten, die im Auffüllungsschritt eingefügt wurden.

The algorithm presented was first run on a server system for automatic character placement in the location sketch. For each of the location sketches, the placement takes less than a second. Assuming client-server communication, this means that the tactical characters are placed without any perceptible delays, so that the calculation phase is not noticed by the user. Especially when zooming and moving the map area, the presented algorithm thus ensures smooth map interactions. In real scenarios, however, a stable connection to a server cannot always be guaranteed, e.g. when operating in tunnels or in sparsely populated areas. In such cases, the automatic placement of tactical points on the devices used on site must be carried out by the user. For this reason, the algorithm was also run on a tablet. Character placement on the tablet took between four and six seconds. Although smooth map interactions are no longer possible with these runtimes, the time delay is within a low range. Even without a connection to the server, location sketches can therefore be created in just a few moments without the need for special software or large computing capacities.

In time-critical operations in particular, where the current situation needs to be recorded and monitored as quickly as possible, automatic sign placement can save important time. This advantage is not only limited to the emergency services on site, but can be transferred to all levels of command. Even higher levels, such as the association and staff work, are relieved by the elimination of the manual placement step. The use of an algorithm also makes it possible to automatically adapt the position sketches to the different requirements of the command levels. For example, while it is important for the platoon leaders on site that the location of each emergency vehicle is labeled, it is sufficient for the command staff to group the vehicles together as a firefighting platoon. Depending on the command level, the presented algorithm offers the potential to generate situation sketches.

The authors also point out that the automatic placement of tactical signs does not rule out subsequent manual processing. Rather, the algorithm presented is to be understood as a supplement to existing digital systems (see Bernsdorf and Fritze, 2016; Lamers and Fortkamp, 2019). The automatically marked location sketches can be used as initial solutions that can be flexibly adapted by the user as required.

Summary and outlook

Although fire departments and disaster control services are now increasingly using digital services to visualize situation sketches, tactical signs are still mainly placed manually. In this context, this article has addressed the potential associated with the automatic placement of signs. Based on the layout of the NRW situation display system, an algorithm was presented in this article that automatically places tactical signs at the edge of the map, taking various criteria into account.

It was shown that, assuming client-server communication, the algorithm performs character placement in less than a second and is therefore also suitable for interactive applications. Even in scenarios in which a stable server connection cannot be guaranteed, the placement is carried out within a few seconds on a standard tablet. Especially with regard to time-critical operations, the authors argue that the transition from manual to automatic placement across all command levels can save time resources and relieve the burden on emergency services.

For a further development of the algorithm, it is conceivable to additionally model the different requirements of different command levels; in particular, it should be possible to automatically generalize a given situation sketch provided with tactical signs for higher levels.

Field tests should be carried out under real conditions in order to be able to assess the practical suitability. For example, the algorithm presented could be used in simulated operations and feedback from the emergency services involved could then be obtained. Possible recommendations and suggestions for improvement could thus be directly identified and subsequently integrated.

Literature

Agarwal, Pankaj K.; Marc van Kreveld & Subhash Suri (1998): Label Placement by Maximum Independent Set in Rectangles, in: *Computational Geometry* 11 (3-4),209-218.

Ahn, John & Herbert Freeman (1983): A Program for Automatic Name Placement, in: *Proc. of the 6th International Symposium on Automated Cartography (Auto Carto Six)*, 444-453.

Bernsdorf, Bodo & Holger Fritze (2016): Digitale Karten und eine geodatenbasierte Lageskizze für den Feuerwehreinsatz, in: *Vereinigung zur Förderung des Deutschen Brandschutzes e. V.*, 65 (4), 171-183.

Cai, Shaowei, Wenying Hou, Jinkun Lin & Yuanjie Li (2018): Improving Local Search for Minimum Weight Vertex Cover by Dynamic Strategies, in: *Proc. of the International Joint Conferences on Artificial Intelligence Organization (IJCAI'18)*, 1412-1418.

Chuzhoy, Julia & Alina Ene (2016): On Approximating Maximum Independent Set of Rectangles, in: *Proc. of the IEEE 57th Annual Symposium on Foundations of Computer Science (FOCS'16)*, 820-829.

Endsley, Mica R. (1995): Toward a Theory of Situation Awareness in Dynamic Systems, in: *Human Factors* 37 (1), 32-64.

Fowler, Robert J., Michael S. Paterson & Steven L. Tanimoto (1981): Optimal Packing and Covering in the Plane are np-Complete, in: *Information Processing Letters* 12 (3), 133-137.

Gemsa, Andrea, Benjamin Niedermann & Martin Nöllenburg (2020): A Unified Model and Algorithms for Temporal Map Labeling, in: *Algorithmica*, 82 (10), 2709-2736.

Haunert, Jan-Henrik & Alexander Wolff (2017): Beyond Maximum Independent Set: An Extended Integer Programming Formulation for Point Labeling, in: *ISPRS International Journal of Geo-Information* 6 (11), 342.

Hirsch, Stephen A. (1982): An Algorithm for Automatic Name Placement Around Point Data, in: *The American Cartographer* 9 (1), 5-17.

Imhof, Eduard (1975): Positioning Names on Maps, in: *The American Cartographer* 2 (2), 128-144.

Lamers, Christoph & Andras Denker (2022): Methoden der Visualisierung in Führungsstäben der Feuerwehr, in: Gesine Hofinger & Rudi Heimann (Hrsg.) *Handbuch Stabsarbeit*, 319-325.

Lamers, Christoph & Guido Fortkamp (2019): Stabsausbildung auf der Höhe der Zeit, in: *Brandschutz/Deutsche Feuerwehr-Zeitung* 73 (1), 7-11.

Lamm, Sebastian, Christian Schulz, Darren Strash, Robert Williger & Huashuo Zhang (2019): Exactly Solving the Maximum Weight Independent Set Problem on Large Real-World Graphs, in: *Proc. of the Twenty-First Workshop on Algorithm Engineering und Experiments (ALENEX'19)*, 144-158.

Liao, Hua, Xueyuan Wang, Weihua Dong & Liqiu Meng (2019): Measuring the Influence of Map Label Density on Perceived Complexity: A User Study Using Eye Tracking, in: *Cartography and Geographic Information Science* 46 (3), 210-227.

Luboschik, Martin, Heidrun Schumann & Hilko Cords (2008): Particle-Based Labeling: Fast Point-Feature Labeling Without Obscuring Other Visual Features, in*: IEEE Transactions on Visualization and Computer Graphics* 14 (6), 1237-1244.

Marín, Alfredo & Mercedes Pelegrín (2018): Towards Unambiguous Map Labeling-Integer Programming Approach and Heuristic Algorithm, in: *Expert Systems with Applications*, 98, 221-241.

Mitchell, Joseph S. (2021): Approximating Maximum Independent Set for Rectangles in the Plane, in: *IEEE 62nd Annual Symposium on Foundations of Computer Science (FOCS'21)*, 339-350.

Morrison, J. L. (1980): Computer Technology and Cartographic Change, in: D. R. F. Taylor (Hrsg.), *The Computer in Contemporary Cartography*, New York: J. Hopkins Univ. Press.

Pardalos, Panos M. & Jue Xue (1994): The Maximum Clique Problem, in: *Journal of Global Optimization* 4 (3), 301-328.

Van Laarhoven, Peter J. & Emile H. L. Aarts (1987): *Simulated Annealing: Theory und Applications*, Dordrecht: Springer Science+Business Media.

Yamamoto, Missae, Gilberto Camara & Luiz A. N. Lorena (2002): Tabu Search Heuristic for Point-Feature Cartographic Label Placement, in: *GeoInformatica* 6 (1), 77-90.

Yoeli, Pinhas (1972): The Logic of Automated Map Lettering, in: *The Cartographic Journal* 9 (2), 99-108.

Link to presentation

https://thga.sciebo.de/s/rkmpUGcXvOoBI43

Technische Hochschule Georg Agricola

Aerial image-based detection of critical hazard objects using synthetically generated training data and deep learning

Michael Hieb(1), Iris Gräßler(1), Jens Pottebaum(1), Ivana Kruijff(2), Martin Stampa(2) und Nicola Rupp(2)

(1) University of Paderborn

(2) German Center for Rescue Robotics

Note:

This article was not submitted for organizational reasons.

Link to presentation

https://thga.sciebo.de/s/H1DoQadcNaBwpkZ

Technische
Hochschule
Georg Agricola

Sensor data fusion and GIS-based approaches to reduce emissions and risks at production and storage sites in the oil and gas industry

Benjamin Haske[1, 2], Bodo Bernsdorf[1] und Tobias Rudolph[1]

(1) Technische Hochschule Georg Agricola University

(2) Technical University Bergakademie Freiberg

Abstract

The article describes a geo-monitoring concept for storage sites in the oil and gas industry and the steps involved in data acquisition and fusion. In terms of plant safety, environmental and climate protection, such sites are vulnerable elements of critical infrastructure. Leaking in gas technology systems lead to the release of large quantities of greenhouse gases, while escaping oil causes considerable environmental damage. The integrity of such facilities therefore plays a role in fire and disaster protection.

The article focuses on the data levels and their integration via the spatial reference in Big Data-type geo-information systems. Derived from classic geo-monitoring concepts, an attempt is made to transfer these to storage monitoring. Elements are in-situ sensors, a drone, a satellite level and their integration into the multidimensional, spatio-temporal tensor. In contrast to previous monitoring methods, the contribution to fire and disaster protection is evaluated.

This is a project-related experiment, which is why the actual benefit cannot be proven. The outlook describes how greater certainty regarding the benefits of the concept is to be achieved in further work steps. The article focuses on the various data levels and their integration via the spatial reference in BigData-like information systems, which are essentially based on modern GIS technologies and the associated analysis methods.

Introduction

In General

Progressive climate change is placing ever greater demands on fire and disaster protection due to increasing extreme weather events, especially in forest fire and heavy rainfall scenarios. The main drivers of this climate change are greenhouse gases, with carbon dioxide (CO_2) being mentioned most frequently in the general discussion, as it is mainly produced when fossil fuels are burned. For a long time, natural gas, which is comparatively easy to burn, was cited as a bridging technology to secure the energy and heat supply in Germany after the nuclear and coal phase-out. However, natural gas consists largely of methane (CH_4), which in turn has a greenhouse effect around 25 times greater than carbon dioxide (Federal Environment Agency, 2022). "For this reason, there are increasing international efforts to reduce these emissions, particularly in the oil and gas industry" (Böttcher, 2022).

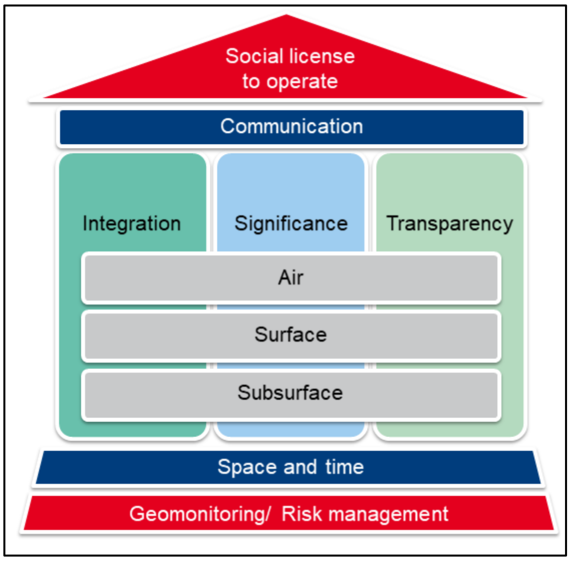


Figure 1: The double triad of geo-monitoring as a basis for communication and the social responsibility of mining and industrial plant operators (Goerke-Mallet et al 2020).

The continuous development of methods to prevent emissions is therefore an important part of the safety-related and social operator responsibility (Figure 1) in the oil and gas industry and has a direct impact on fire and disaster prevention. The Post-Mining Research Centre uses interdisciplinary approaches from remote sensing and geoscientific methods to develop safety solutions for critical infrastructures and post-mining landscapes (Post-Mining Research Centre 2020). "The use of state-of-the-art satellite and drone technology is not intended to replace established procedures, but to complement them in a meaningful way and make them more effective and efficient" (Haske et al. 2021, Haske et al. 2022). Monitoring includes the plants themselves, but also boreholes, pipelines and the surrounding area. "Unwanted emissions are detected either directly (e.g. by UAV-based thermal or gas cameras; Bernsdorf et al. 2020) or indirectly" (e.g. by satellite-based, multispectral vegetation monitoring Bernsdorf et al. 2023) and "are supplemented and validated by conventional geoscientific methods and on-site measurements" (in situ).

"It has been shown that comprehensive safety monitoring requires the use of different data sources and sensor types" (Haske 2021). This data must be jointly analyzed, merged and interpreted in a 4-dimensional, spatio-temporal context in a multi-stage process.

The common denominator here is the high-precision geo-localization of the various data sources, which enables a joint, GIS-based evaluation. By creating clearly structured and user-friendly web interfaces, these evaluations can also be made available to people without a geoscientific background in order to use these real-time analyses for monitoring tasks, decision-making processes or transparent public relations work (Rudolph et al 2023).

The degree to which information is passed on can be set at a granular level so that internal company data remains protected.

Recent Monitoring

This article was motivated by enquiries from the gas industry. According to a plant manager, one problem with efficient damage detection is the existing system and the low legal requirements. As high pressures of up to 200 bar are used, major damage can be quickly localized acoustically. Minor damage is not easily noticed. Regular visual inspections are therefore mandatory. Gas detectors and classic leak detection sprays are used in the event of anomalies. Considering a gas system with thousands of flanges and kilometers of pipes, this is a complex, labour-intensive and expensive process. A more modern variant is the detection of faults using technical system approaches. Pressure and other sensors are used here, as described in Doshmanziari et al. 2020 or Rao et al. 2012. Here, too, a laborious search must be carried out in the event of anomalies, even if system areas or pipe sections can be better localized. There are few requirements for transport lines. A visual inspection by helicopter is carried out once a year. A DLR concept, the CHARM® helicopter, which is capable of detecting methane molecules via laser measurements, is rarely used due to the high costs involved (DLR-undated, OGE-undated).

The intermediate level is covered in rare cases. For this purpose, a ground-based gas detection device is mounted on a vehicle and the area or routes along a pipeline are travelled. The device is equipped with a GNSS sensor so that peaks can be easily localized in post-processing.

Procedure

"*Monitoring concepts, as in this case for the reduction of emissions and risks at production and storage sites in the oil and gas industry, must always be developed on a site-specific and application-oriented basis*" (Doshmanziari et al. 2020, Rao et al. 2012). However, a simple methodology has emerged for development at the Research Centre for Post-Mining:

First, extensive site knowledge and process understand is created by using open data sources (e.g. the geoportals of the federal and state governments), data from participating stakeholders (companies, authorities, municipalities) and own measurements. This is important for the subsequent evaluation of the monitoring data, creates transparency for all participants and minimizes misinterpretations.

To validate the remote sensing data to be integrated later, ground control points (GCPs) are identified or created using high-precision measurements. The sensors and platforms to be used for the respective application are then identified and incorporated into the concept. They should be selected so that they complement and balance each other's strengths and weaknesses in the areas of spatial, temporal and spectral resolution and match the expected damage events or emissions (Haske 2021).

Finally, automated workflows are created that analyze and validate the resulting remote sensing data and initiate appropriate measures in the event of damage. The situation is visualized in an easy-to-use web GIS. The aim here is multi-level, multi-temporal monitoring of the respective location (Figure 2).

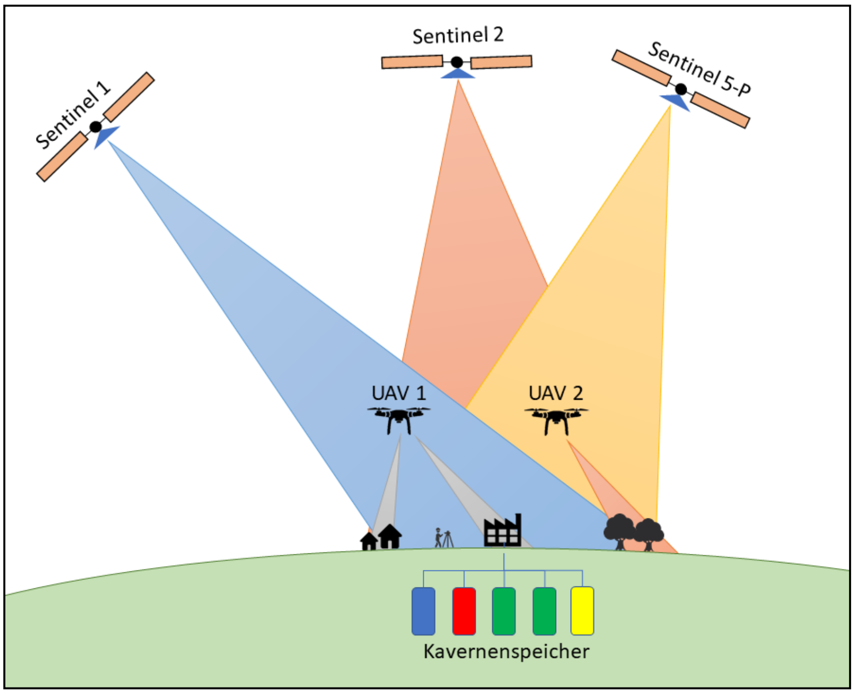


Figure 2: Multi-stage monitoring model for monitoring production and storage sites in the oil and gas industry, here using the example of an underground cavern storage facility. The colors of the symbolic caverns indicate different media that are stored (e.g. methane, crude oil, various gases such as helium, etc.) (Haske, Rudolph, & Bernsdorf, 2021).

Results

As already mentioned in the previous chapter, the structure of the respective monitoring concept must always be individually adapted to the site and its particular characteristics in terms of topography, geology, land use and possible sources of danger. This article presents the results of the Ka-MonSys project (monitoring system for the plant and supply safety of cavern storage facilities using satellite and copter data) funded by the Federal Ministry of Education and Research (BMBF) 2020. Here, the Research Centre for Post-Mining, together with the project partner EFTAS Remote Sensing Technology Transfer and the associated partners Gas and Heat Institute of Essen, Salt Production Company of Westphalia and Uniper Energy Storage, has developed a monitoring system for one of the largest underground storage facilities for oil and gas in Europe (Research Centre for Post-Mining 2020).

The data levels involved in the integration and analysis process are presented below. Each data level plays to its strengths - but also introduces weaknesses into the system. Static cartographic information from the web services provides the spatial reference, but the situation at the time of data collection and is supplemented by dynamic satellite or threat data. Satellite data, which is disadvantaged in terms of geometric ground resolution, provides a small-scale overview of large areas, but cannot recognize details. The drone level, on the other hand, can only be used on a small scale but at large scales with a high geometric resolution. The aim of a monitoring system must therefore be to be able to access all data levels, but also to be able to act individually in each case (e.g. satellites in the area of regular observation and early warning, drones in the detailed observation of leaks in buildings, for example). "In a multi-risk assessment, these levels can be 'interconnected' in different phases of the monitoring concept, which corresponds to a sequence of the Analytical Hierarchy Process (AHP)" (Saaty 2012).

Initial data collection

By using our own measurement and archive data, data from project partners and a large number of open data sources, a very large geodata pool can be compiled in a very short time and used to create an understand of the location (Figure 3). Particularly noteworthy is the extensive and open data provision by Geobasis NRW (Cologne District Government 2023) with the spatially, temporally and thematically diverse data provided under the "Data License Germany - Zero". Geobasis NRW is an exemplary implementer of the European Commission's INSPIRE initiative, which aims to create a European spatial data infrastructure for the purposes of a common environmental policy (European Union 2007).

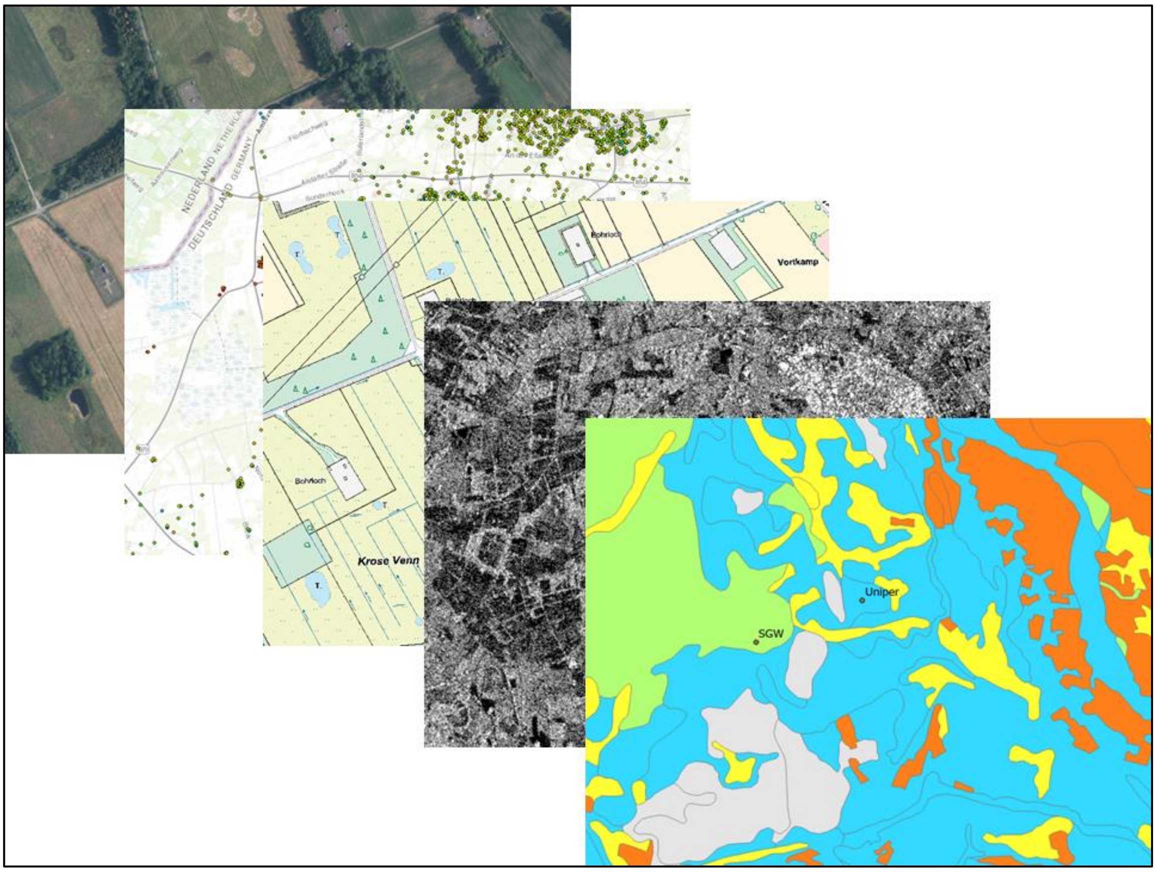


Figure 3: Exemplary overlay of various data sets used for the evaluation of the project site: From back to front: digital orthophotos, ESRI base map with data from the ground movement service,digital topographic map 1:10,000, radar image (Sentinel-1), information system soil maps 1:50,000 with the locations of the associated project partners (Haske et al. 2021).[2]

From the multitude of available data sources, the KaMonSys project then selected those required for a comprehensive understand of the geological, biogenic and anthropogenic surface and underground situation at the storage site. In a labour-intensive process, the data, which was

[2] For data protection reasons, no north arrow, scale and coordinate grid have been used in this and the following illustrations.

available in a wide variety of formats, was evaluated, homogenized and prepared for GIS-based use.

"Nowadays, this data is no longer only available as a 2D projection, but in many cases can also be used for meaningful 3D visualizations" (Figure 4) (Haske 2023).

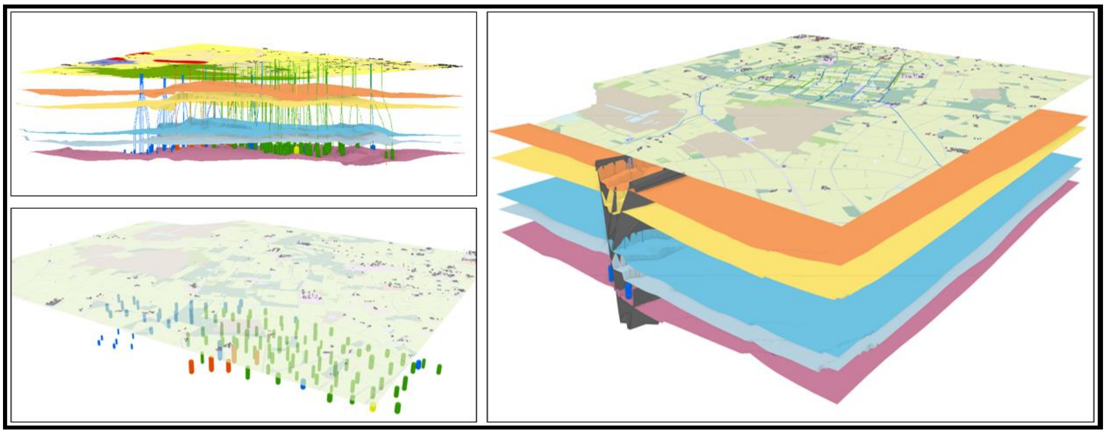


Figure 4: 3D GIS from open geodata provided by the project partners. Top left: Side view with boreholes, geological layers and caverns (blue = brine, green = natural gas, red = crude oil, yellow = helium). Bottom left: Transparent oblique view with all data, including geological faults. The data gap marks the border with the Netherlands. Bottom right: 3D view of the project area (Haske 2023).

Satellite Segment

Due to the high spatiotemporal resolution, satellite remote sensing is particularly interesting for long-term and wide-area geo-monitoring, as required for risk management in the oil and gas industry. The availability of current remote sensing data is subject to constant change. Due to technical progress in the fields of sensor, aerospace and aeronautical engineering, new data sources are constantly being developed, while others are becoming uninteresting or uneconomical due to outdated technology. Due to their comparatively good sensor technology, modern technology and free use of data, the data from ESA's European Copernicus programme (European Space Agency, no date) is particularly suitable. Although other commercial satellite constellations can often offer a higher resolution, they are not an option for long-term monitoring due to their high costs. The three systems Sentinel-1, Sentinel-2 and, to a limited extent, Sentinel-5P are particularly useful for reducing emissions and risks at production and storage sites in the oil and gas industry (Figure 7).

Sentinel-1

The system was launched with two satellites and two further launches are planned. The satellites fly 180° offset at an altitude of 683 km in a near-polar, sun-synchronous orbit and record every point on Earth every 6 days with a C-band SAR (Synthetic Aperture Radar) sensor (European Space Agency, no date). Due to the failure of Sentinel-1B in 2022, this rhythm cannot currently be maintained. The sensor can be swiveled and focused so that different viewing angles, resolutions and swath widths can be used depending on the application.

"InSAR evaluation (Interferometric Synthetic Aperture Radar) allows ground movements in particular to be recorded with high precision" (Hanssen 2001), so that "it has now become a standard procedure in this area" (Adam et al. 2020). Although it cannot provide direct conclusions about harmful emissions, it can possibly predict damage to pipelines or facilities caused by ground movements in good time. In the Epe area, for example, the subsidence trough of the cavern storage facilities can be monitored with high temporal and spatial resolution (Figure 5). The Post-Mining Research Centre is also currently conducting research into using the data from Sentinel-1 for soil moisture monitoring (e.g. Yin et al. 2022).

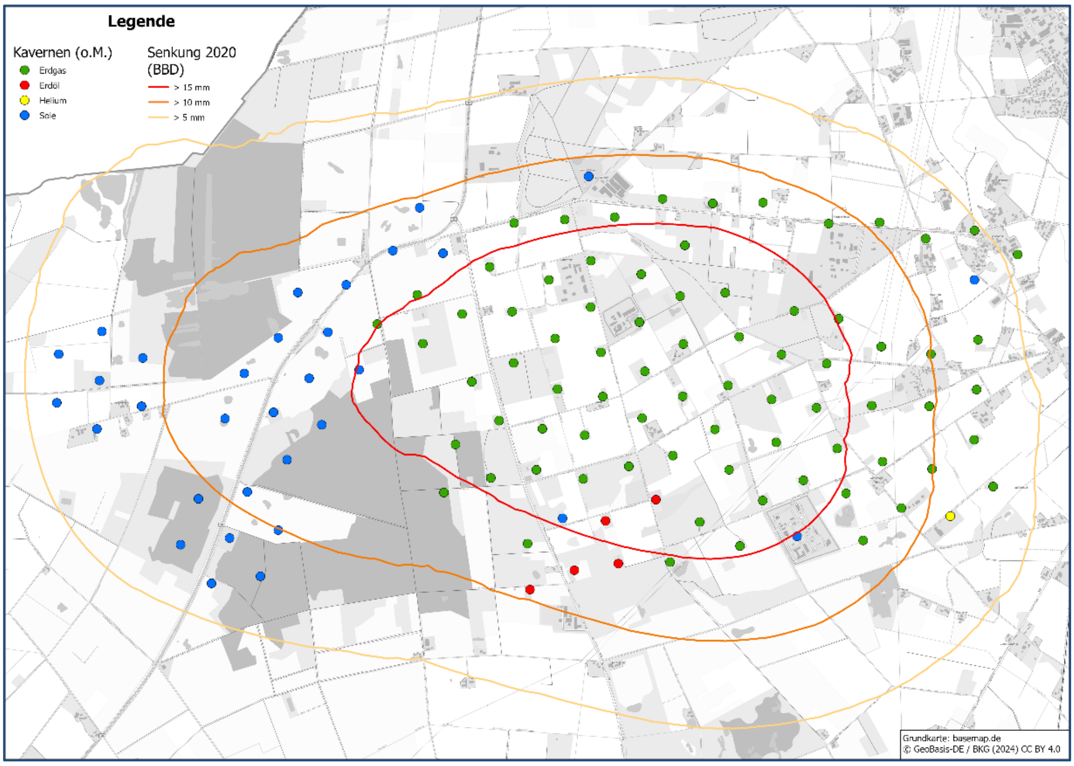


Figure 5: ***Sinkhole calculated for one year over the Epe cavern field from data from the German Ground Movement Service (Federal Institute for Geosciences and Natural Resources 2021) (InSAR evaluation of Sentinel-1 data)(Haske 2023).***

Sentinel-2

The Sentinel-2 satellite tandem consists of two identical systems which, like Sentinel-1, fly in a sun-synchronized orbit offset by 180°. The high-resolution passive CMOS sensors record data in a total of 12 spectral bands (from 442.7 nm to 2202.4 nm) from an altitude of 786 km, which can be used for climate protection and disaster and crisis management, among other things (European Space Agency no date). In particular, "the calculation of vegetation indices" (Pawlik et al. 2021), "which use infrared channels in addition to visible light, allows indirect effects of emissions to be recognized quickly" (Köhler 2019). Leaking gases or crude oil can lead to vegetation damage within a short period of time. A before-and-after comparison of two satellite scenes at short intervals can be used to estimate the change in vegetation (Figure 6) and atypical changes can be recognized using a Gaussian normal distribution. "If a strong deterioration occurs within a short period of time in the spatial context of pipelines or technical facilities, this may indicate a leakage" (Haske 2023). In most cases, however, these are false positives, such as recently harvested fields or construction work. The knowledge of the location gained in advance as well as a closer inspection by drone or inspection can provide information here.

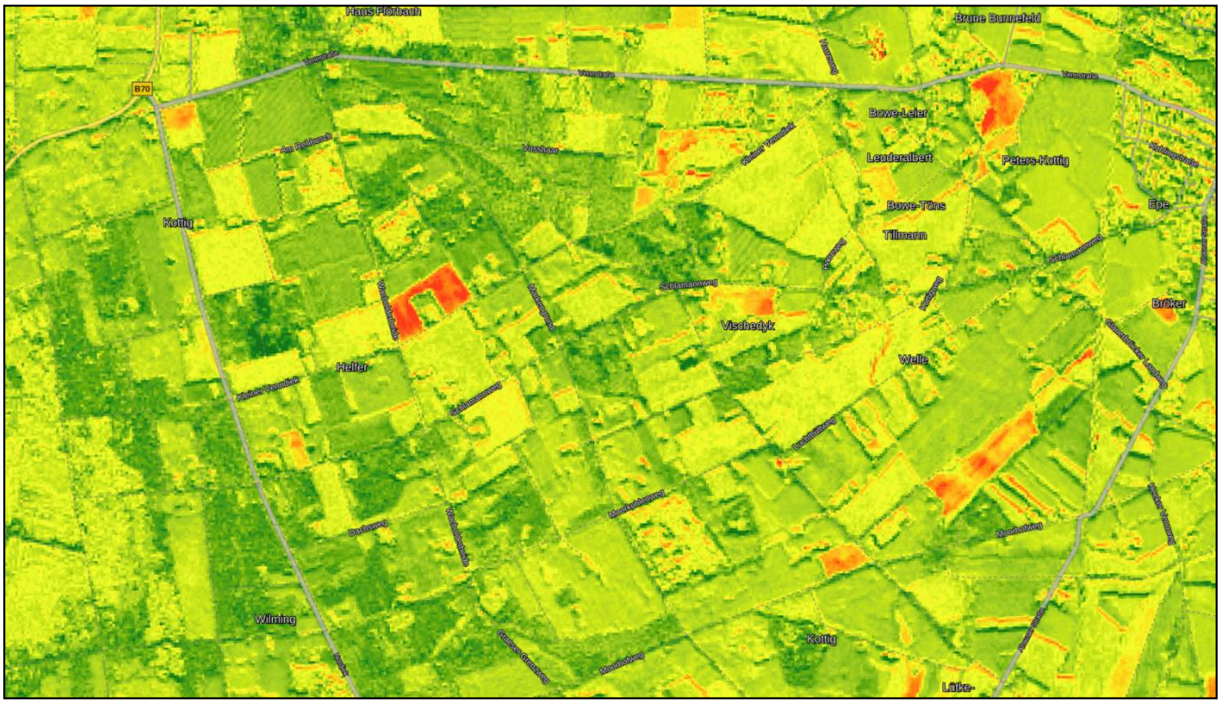


Figure 6: Calculation of the change in vegetation quality (MSAVI, Modified Soil Adjusted Vegetation Index) between two satellite images of the cavern field in spring. Green = improvement, yellow = stable, red = deterioration (Haske 2023).

Sentinel-5P

Sentinel-5P (Precursor) is the precursor mission to Sentinel-5, which is intended to close the data gap left by the failed Envisat until the latter becomes operational. The single satellite is travelling in a sun-synchronous orbit at an altitude of 824 km. The Tropospheric Monitoring Instrument (TROPOMI) on board records every point on Earth in a 16-day cycle (European Space Agency, no date) in order to measure various gas concentrations in the atmosphere (Figure 7). However, as the resolution is several kilometers, it is only suitable for searching for local emission sources to a very limited extent. During the 2-year KaMonSys runtime, no events were detected in the Gronau-Epe area.

The method was validated using a real case study (oil spill on the Druzhba pipeline in Poland on 12th October 2022, Köppe 2022).

Drones Segment

For some years now, unmanned aerial systems (UAS-German Institute for Standardization, 2018), colloquially referred to as "drones" in the following text, have been increasingly used for monitoring tasks. In contrast to aeroplanes, helicopters and satellites, they offer more flexible deployment options, lower flight costs and significantly higher resolutions due to lower flight altitudes. This is offset by legal aspects (no-fly zones, authorizations), weather-related restrictions, lower spatial coverage and the low temporal resolution associated with these points. “To compensate for these advantages and disadvantages, drone and satellite data should therefore always be used together for monitoring” (Haske 2021). The regular satellite images can thus be "sharpened" by the spatially high-resolution drone images (Figure 8). Both data sources can validate each other through their high-precision geo-referencing.

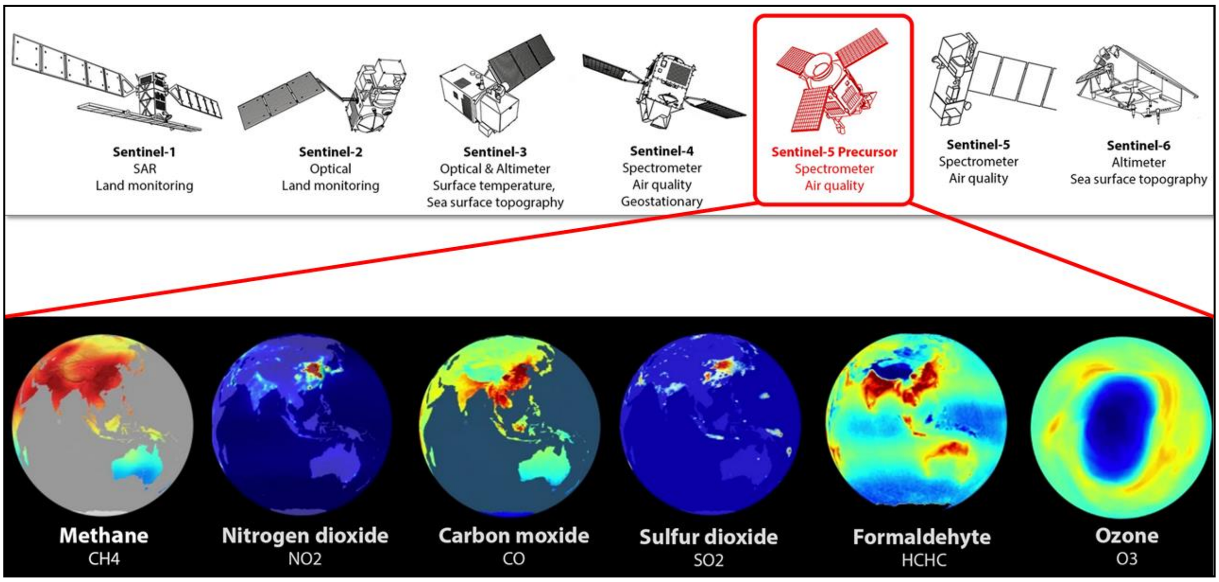


Figure 7: The Sentinel satellites of the European Copernicus programme. In focus: The sensors of Sentinel-5P, adapted from (European Space Agency, no date).

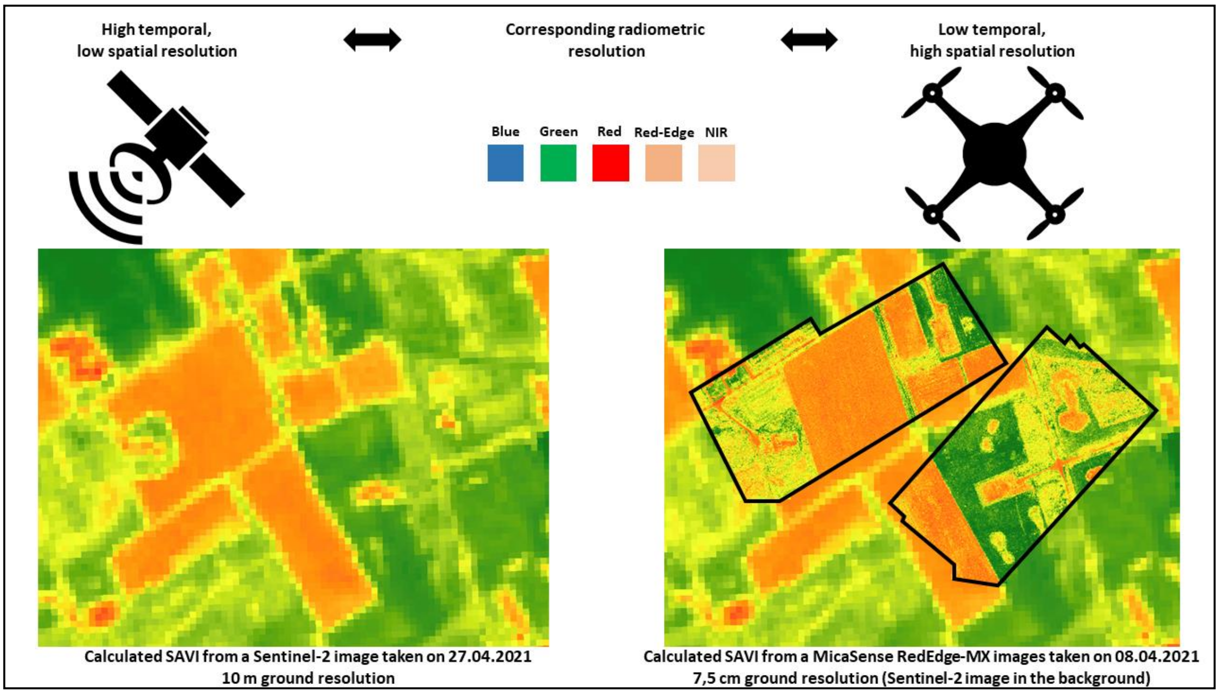


Figure 8: Comparison between the spatial, temporal and geometric resolution of the Sentinel-2 satellite and a drone-based MicaSense RedEdge-MX camera (Bernsdorf et al 2023).

“As with satellites, a wide range of different active and passive sensors have been developed in recent years” (Toth & Jutzi 2017). For the KaMonSys monitoring project, several drones from the market leader DJI were selected from the wide range of options:

- Phantom 4 RTK for high-precision 2D and 3D surveying
- Phantom 4 Multispectral for capturing images in different wavelengths
    - Blue (B): 450 nm ± 16 nm
    - Green (G): 560 nm ± 16 nm
    - Red (R): 650 nm ± 16 nm
    - Red Edge (RE): 730 nm ± 16 nm
    - Near-Infrared (NIR): 840 nm ± 26 nm
- Mavic 2 Enterprise Advanced for thermal infrared images and videos

All three drones have an integrated or modular RTK (Real Time Kinematic) module, which improves the positional accuracy in flight and the geo-localization of the images from several meters to a few centimeters via the SAPOS satellite positioning service, which is freely available in NRW (Cologne District Government 2023).

With the help of the Phantom 4 RTK surveying drone, the facilities and some selected surrounding areas were initially surveyed and high-resolution 2D orthophotos, 3D and elevation models were created using special photogrammetric software. These are used to verify the other sensors, but can also be used for initial damage assessments or measurements of ground movements. In addition, highly accurate, textured 3D models of the respective locations are created, which are used for the high-precision 3D flight planning of the other drones. The focus here is on safe flight through the plant, taking topography, buildings, facilities and protection zones into account. The aim is to bring the sensors as close as possible to the potential emission or damage points during the automated flight, while remaining outside the previously defined protection and no-fly zones.

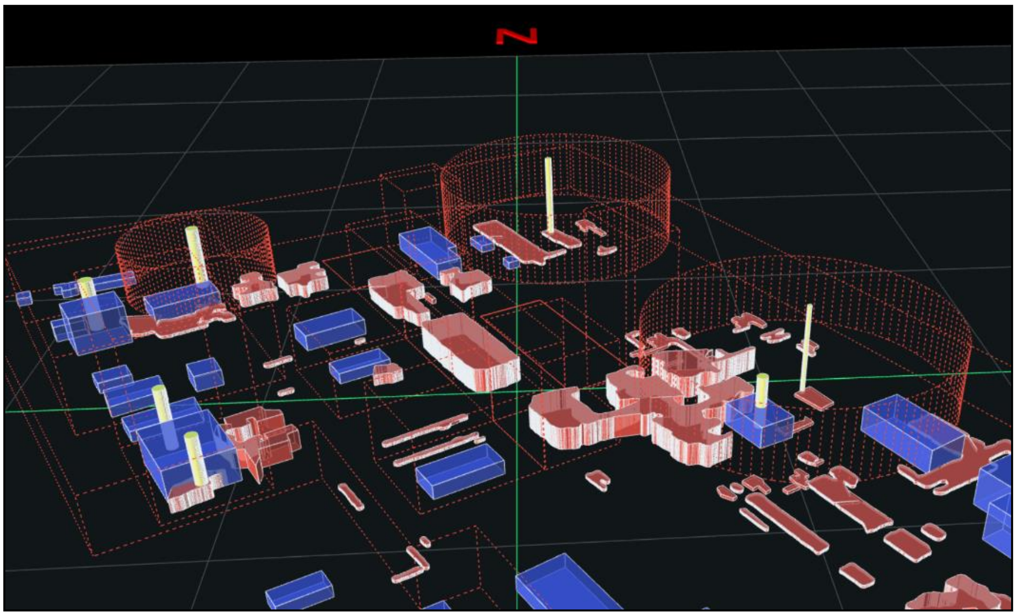


Figure 9: Modelling of a gas plant for high-precision 3D flight planning. Red = gas installations, yellow = chimneys, blue = other buildings, red dotted = protection and no-fly zones (Haske et al 2021).

The models can also be used as a "by-product" for site management, fire brigades and rescue services (Figure 10).

Figure 10: Interactive, textured 3D model of a gas facility, created from images taken by a DJI Phantom 4 RTK; Agisoft Metashape photogrammetry software (Haske 2021).

One of the focal points of the project was also the cost-effective detection of emissions using a thermal infrared camera in comparison to dedicated gas sensors. Here, the cooling of the gas during decompression is utilized via the Joule-Thomson effect (Joule & Thomson 1852). The gas escaping from a leak cools itself and the system components noticeably, so that both can be detected by the heat-sensitive infrared camera. "As the exact procedure (subpixel matching, change detection, etc.) would go beyond the scope of this article, we refer to other publications in this field" (Bernsdorf et al 2020).

In-Situ Segment

For the in-situ segment to validate the remote sensing data, ground control points were surveyed and marketed using conventional surveying methods (GNSS, tachymetry). In addition, live data from the respective operators, meteorological data and the location knowledge of the residents were used.

GIS-based Data Fusion

All the data collected, provided and added by regular drone and satellite overflights was collated in a large 3D geo-information system. The high-precision geo-referencing of all data enabled it to be analyzed and displayed in different layers for specific applications. Figure 12 shows an example of the merging of the various thematic layers of topography, geology, hydrology, historical data, mining cracks and remote sensing data.

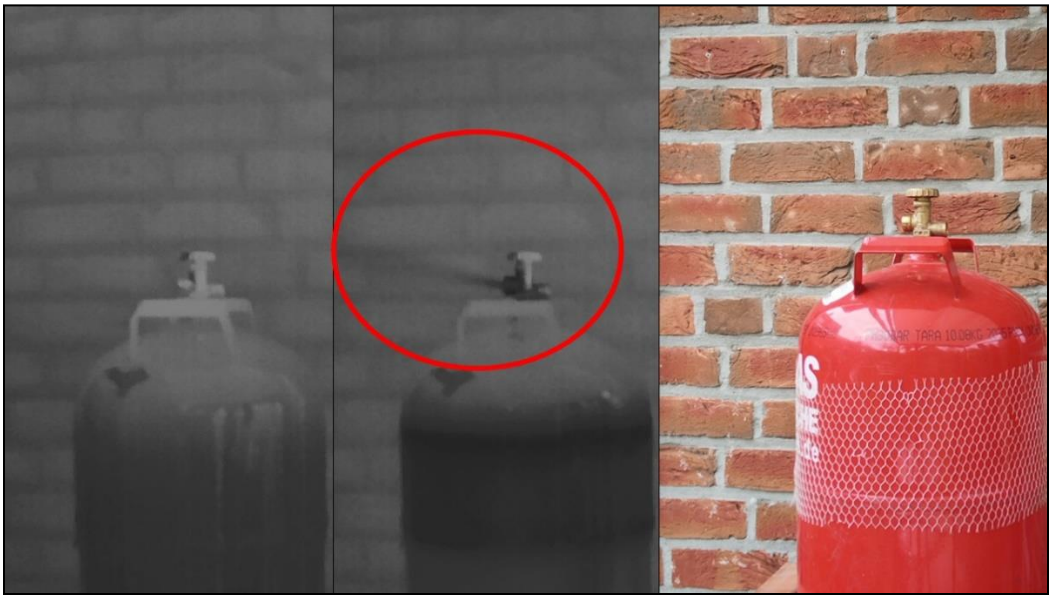


Figure 11: Simple gas detection using a DJI Mavic 2 Enterprise Advanced drone. Left = temperature of the cylinder in normal condition, center = cooling of the air and valve during gas leakage visible in the thermal infrared image (dark), right = gas leakage not visible in the simultaneously recorded RGB video.

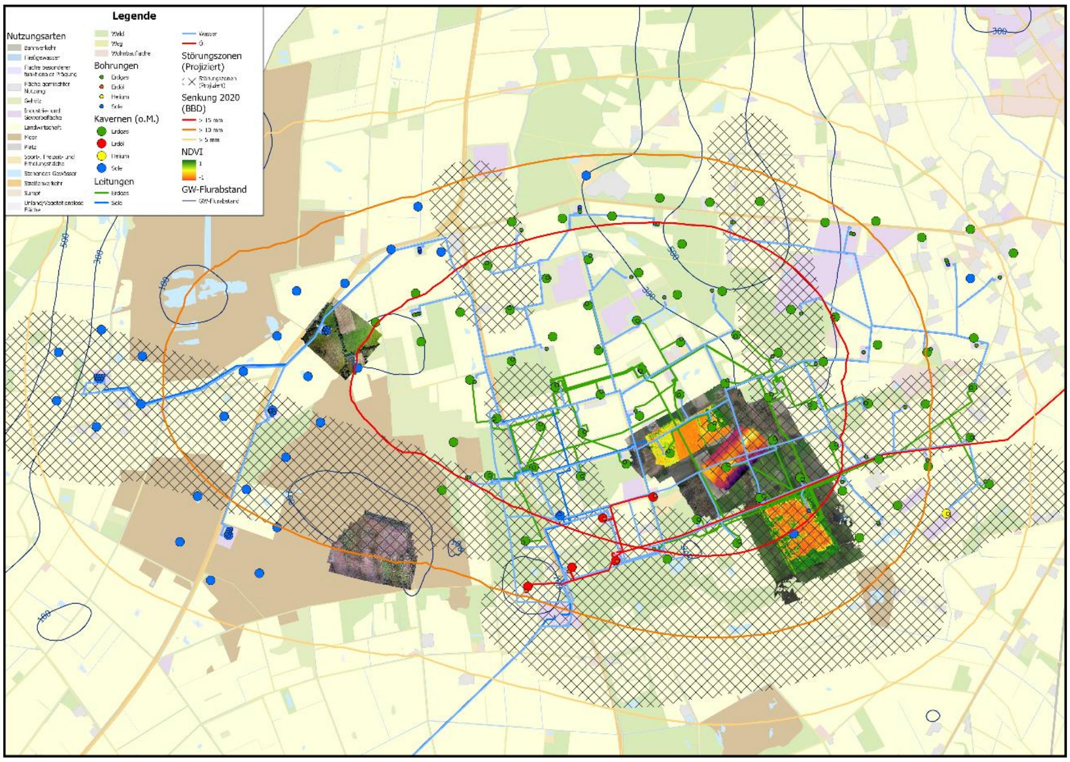


Figure 12: The interactive GIS from the KaMonSys project. As an example, layers with information on pipelines, boreholes, caverns, land use, groundwater distances, subsidence and geological faults are displayed together with analyses of multispectral UAV flights (RGB, thermal infrared, NDVI) (Bernsdorf et al 2023).

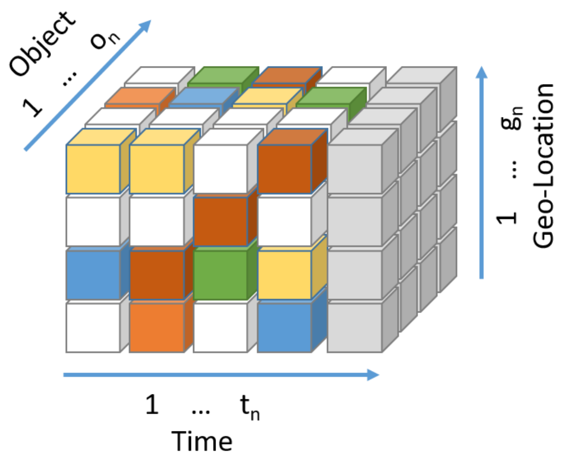


Figure 13: Spatiotemporal data tensor as a big data geo-repository (Bernsdorf et al. 2023; own design)

The fusion method is based on a BigData-approach. The data silos of the different observation levels (in-situ, UAV, satellites, external data) are - as described - essentially subject to data fusion in the form of integration into a geo-information system, whereby a multi-dimensional spatio-temporal data tensor is created (Figure 13). The actual (sensor) data fusion is carried out according to classic BigData schemes, as the data is extremely different in terms of volume, velocity, variety and veracity (4Vs; Gartner n.d.). It is important to be aware that the data from the input sources involved differ in terms of their metrics but still need to be related to each other. In situ sensors may measure every second at exactly one point around the clock for many years; UAVs use high-resolution sensors to fly over areas in various areas of the electromagnetic spectrum, but are rarely used; Satellites have lower geometric ground resolution than, for example, UAVs, but cover large areas with high temporal resolution (overflight frequency of the Copernicus satellites, e.g. 5 to 6 days); Map archives may be patchy and not available across the board. The actual reference and basis for fusion in these different data sets must therefore be the spatial reference. Because all events, maps, sensor data, individual measurements, etc. have the spatial reference as a connecting element: They can be directly assigned to a location or a part of the system (compressor station, drill head, transport line). "The metrics are different - from 'exact' described via a pair of coordinates (e.g. flange, primary metric) to 'inaccurate' valid for a specific anagen section (secondary metric)" (Bill 2023).

The temporal aspect is also a unifying element, as events such as pressure losses due to pipe damage generally have to be limited in time. In this way, the multidimensional, spatiotemporal tensor is created (Figure 13), which contains all the raw data from the input sensors as a big data geo-repository. The methods for integration are "classic" in environmental and geo-monitoring: geo-referencing, geo-coding and geo-tagging are used to integrate the raw data with the correct spatial reference. Temporal aspects can be used to apply filters to events of interest. Strategies for dealing with data gaps are also integrated (e.g. spatial interpolation if a sensor fails). Classic filters are also generalizations/homogenizations or aggregations, for example via such interpolations – geo-statistical methods such as kriging, inverse distance weighting, etc., which are provided by the GIS software. In the form of the above-mentioned Analytical Hirachical Process, "priorities can now be set and statements derived in the form of a multi-risk approach" (Saaty 2021).

Web application for user

When creating a web application - based on ArcGIS online - the main focus is on the ease of use of the versatile data collected. The potential users of the concept are primarily the personnel in control centers and control rooms of storage and production facilities in the oil and gas industry. It must therefore be possible to use all functions without any geo-scientific background knowledge. The site was therefore presented in a simple dashboard in which all measured values, geo-data and monitoring ring results can be easily accessed via a browser (Figure 14). The interface can be operated intuitively and interactively, while all geo-analyzes run in the background.

Active buttons can be used, for example, to easily recognize possible leaks detected by the satellite segment, compare them with the available data, make an initial assessment and, if necessary, take initial measures. One of these measures could be to plan and manually start a drone flight with the corresponding sensors directly via the portal.

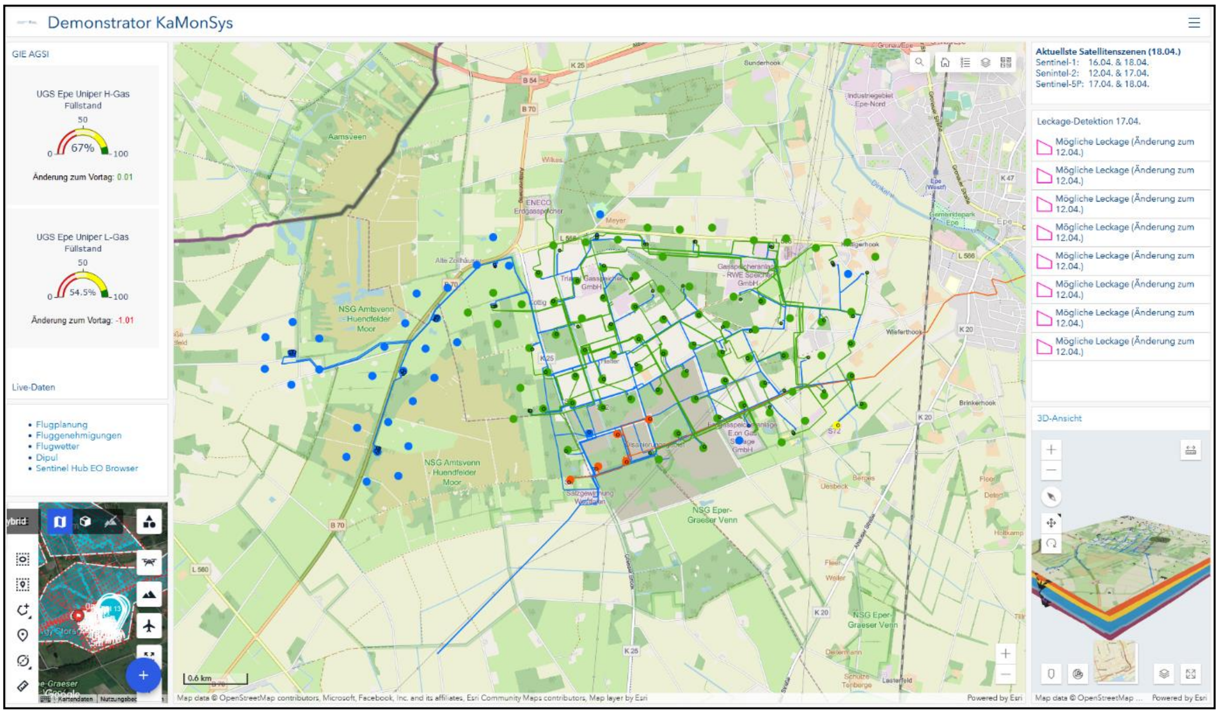


Figure 14: The KaMonSys demonstrator as an example of a simple web dashboard. The 2D and 3D maps can be operated interactively, possible leaks from the satellite segment can be assessed and drone flights can be planned if necessary (Haske 2023).

Contribution to fire and desaster protection

Firstly, the approach presented here essentially contributes to plant safety, as escaping media always represent a safety risk for operation. Especially when it comes to flammable hydrocarbons. However, a geo-monitoring approach also always focuses on environmental protection and - in the case of gas technology systems - such a concept makes a particular contribution to climate protection, as CH_4 - as described - is an extremely harmful greenhouse gas. In this respect, it helps to achieve environmental and climate targets. In addition, the approach can be integrated into the organizational processes of hazard prevention. Similar to the CCFireSense project (Fürstenberg 2022) in the area of vegetation firefighting, where the satellite level triggers a drone level, regular monitoring using in-situ sensors in combination with large-scale satellite image analyses can be developed into an early warning system. Such a system can be connected to control centers of plant or municipal fire brigades, for example, and works in addition to the usual safety equipment of such industrial plants. This can be used preventively or in the event of an incident to call in the threat level (fire brigade units and aid organizations) to initiate detailed investigations. Information (e.g. metadata, live data) can also be transmitted directly to the emergency response control centers via the web level shown in order to obtain an initial picture of the situation.

Early warnings can also be initiated at the prevention stage by regularly analyze multi-spectral satellite data. The oil leak in a Münsterland oil cavern of the National Oil Reserve in Gronau in 2014 (WDR 2014) could very probably have been detected earlier and the damage contained if regular monitoring had been scheduled in the area concerned. As shown in Figure 6, many conclusions can be drawn from vegetation indices. For example, the displacement of water and soil air in grassland leads to reduced plant vitality and can be recognized with regular monitoring. This is not a task for fire and disaster control organizations. However, monitoring by the operators using the concept presented here can at least speed up reporting to the responsible authorities.

Summary and outlook

If one compares the status of current damage monitoring described in the introduction with the sensor data fusion presented here and the GIS-based approaches using in-situ sensors, satellite and drone data, it can be assumed that the reduction of emissions and risks at production and storage sites in the oil and gas industry can be made significantly more effective and efficient due to the process speed alone. The multi-level monitoring concept makes it possible to balance the strengths and weaknesses of the individual systems and sensors and thus ensure comprehensive, spatio-temporal risk management. The individual system components can be modularly adapted and combined to suit the respective application and area of investigation, making this approach suitable for other branches of industry as well.

It should be noted, however, that this is a concept that is not in widespread use and must first prove its suitability in real operations.

Nevertheless, or perhaps precisely because of this: further projects on 3D modelling and multi-sensor drone flights of production and storage sites in the oil and gas industry, vegetation analysis for the detection of gas leaks at old wells, research and training for the use of multi-sensor drones in fire and disaster protection as well as further collaborations on drone-based building inspections and area monitoring have already started or are planned. The knowledge gained in the project on data acquisition, geo-data management, geo-analysis, drone flight planning and data processing can be actively used and their suitability tested in real laboratories.

Acknowledgements

The authors would like to thank the project partner EFTAS Remote Sensing Technology Transfer GmbH for good co-operation in the KaMonSys project and the associated partners Gas and Heat Institute of Essen, Salt Production Company Westphalia and Uniper Energy Storage for access to data, facilities and expert knowledge.

We would also like to thank the StartING@THGA initiative and the RAG-Stiftung for providing various professional drones for this and other research projects.

Technische Hochschule Georg Agricola

Literature

Bernsdorf, Bodo, Anna Formaniuk &Tobias Rudolph (2020): Possibilities of a Method for Copter-Supported Gas Leak Detection With Therma Imaging Cameras in Industry and Hazard Prevention, in: *Oil & Gas - European Magazine*, 46th ed. Issue 4/2020, 13-20.

Bernsdorf, Bodo, Julia Haske & Benjamin Haske (2023): Geomonitoring as an Instrument to Accompany Structural Changes in Post-Mining Areas, in: *Managing the Change: Tasks of Post-Mining in Ukraine*, Bochum: Selbstverlag der Technischen Hochschule Georg Agricola, 92-117.

BodenBewegungsdienst Deutschland (BBD). Bundesanstalt für Geowissenschaften und Rohstoffe (2021): https://bodenbewegungsdienst.bgr.de [28.07.2023]

Böttcher, Christian (2022): Aktualisierung der Emissionsfaktoren für Methan für die Erdgasbereitstellung, Dessau-Roßlau: Umweltbundesamt.

Bundesministerium für Bildung und Forschung (BMBF), Referat Zivile Sicherheitsforschung (2020): Monitoringsystem für die Anlagen- und Versorgungssicherheit von Kavernenspeichern mittels Satelliten- und Kopterdaten (KaMonSys), Bonn.

Deutsches Institut für Normung e.V. (2018): DIN 5452-1:2018-03: Luft- und Raumfahrt - Unbemannte Luftfahrzeugsysteme (UAS) - Teil 1: Begriffe. Berlin: Beuth Verlag, https://www.beuth.de/de/norm/din-18716/271892549 [16.05.2024].

European Parliament and of the Council of the European Union (Hrsg.) (2007): Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE), https://knowledge-base.inspire.ec.europa.eu/publications/directive-20072ec-european-parliament-and-council-14-march-2007-establishing-infrastructure-spatial_en [17.05.2024].

DLR - Deutsches Zentrum für Luft- und Raumfahrt (o.J.): Erdgasleitungsprüfung aus der Luft (CHARM(R); Präsentation 2, https://www.dlr.de/tp/Portaldata/39/Resources/Hand-out_CHARM.pdf [17.05.2024].

Doshmanziari, Roya, Hamid Khaloozadeh & Amirhossein Nikoofard (2020): Gas Pipeline Leakage Detection Based on Sensor Fusion Under Model-Based Fault Detection Framework, in: *Journal of Petroleum Science and Engineering*, 12, https://doi.org/10.1016/j.petrol.2019.106581 [17.05.2024].

European Space Agency (o.J.): Europe's Copernicus Programme, https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Europe_s_Copernicus_programme [27.07.2023].

European Space Agency (o.J.): Sentinel-1, https://sentinel.esa.int/web/sentinel/missions/sentinel-1 [27.07.2023].

European Space Agency (o.J.): Sentinel-2 Mission Guide, https://sentinel.esa.int/web/sentinel/missions/sentinel-2 [27.07.2023].

European Space Agency (o.J.): Sentinel-5P, https://sentinel.esa.int/web/sentinel/missions/sentinel-5p [27.07.2023].

Forschungszentrum Nachbergbau (2020a): Unsere Forschungsschwerpunkte https://fzn.thga.de/forschung/ [27.07.2023].

Forschungszentrum Nachbergbau (2020b): KaMonSys: Monitoringsystem für Kavernenspeicher, https://fzn.thga.de/forschung/kamonsys/ [27.07.2023].

Technische Hochschule Georg Agricola

Fürstenberg, Kai. (2022): CCFireSense – die Zukunft des Vegetationsbrandgefahren-Monitorings. ArcGIS StoryMap. https://www.giscloud.nrw.de/arcgis/apps/storymaps/stories/56d65734b8064ee2ab72c0ec24237a4a [17.05.2024].

Gartner Inc. (o.J.): Big Data, in: *Gartner Glossary*; Information Technology. https://www.gartner.com/en/information-technology/glossary/big-data [24.01.2024].

Geobasis NRW. Bezirksregierung Köln (2023): https://www.bezreg-koeln.nrw.de/geobasis-nrw [27.07.2023].

Goerke-Mallet, Peter, Tobias Rudolph, Jürgen Kretschmann & Jürgen Brune (2020): The Importance of „Social License to Operate" for the Mining Life Cycle, in: *Mining Report Glückauf* 156 (4), 323-332.

Hanssen, Ramon F. (2001): Radar Interferometry - Data Interpretation and Error Analysis“, in: Ramon F. Hanssen (Hrsg.), *Remote Sensing and Digital Image Processing*, Dordrecht: Springer.

Haske, Benjamin (2023a): Satelliten- und Drohnen-gestützte Monitoring-Konzepte für Produktions- und Speicherstandorte der Öl- und Gasindustrie, NACHBergbauzeit in NRW.

Haske, Benjamin (2023b): ESRI Map Book - Underground Oil and Gas Caverns at a Storage Facility in Germany, https://www.esri.com/en-us/esri-map-book/maps#/details/7/4 [23.07.2023].

Haske, Benjamin (2021): Die Anwendbarkeit frei verfügbarer Fernerkundungsdaten bei Fragestellungen in Risikomanagement-Systemen des Alt- und Nachbergbaus. Bochum: Masterarbeit, Technische Hochschule Georg Agricola.

Haske, Benjamin, Tobias Rudolph & Bodo Bernsdorf (2021): Sustainability in Energy Storages - How Modern Geoscience Concepts Can Improve Underground Storage Monitoring, EAGE GET2021- 2nd Geoscience & Engineering in Energy Transition Conference, https://www.earthdoc.org/content/papers/10.3997/2214-4609.202121014 [17.05.2024].

Haske, Benjamin, Tobias Rudolph & Peter Goerke-Mallet (2022): Anwendbarkeit frei verfügbarer Fernerkundungsdaten für Risikomanagementsysteme des Alt- und Nachbergbaus, in: *GeoResources* 1, 45-49, https://www.georesources.net/download/GeoResources-Zeitschrift-1-2022.pdf [17.05.2024].

J.P, Joule und W. Thomson (1852): On the Thermal Effects Experienced by Air in Rushing Through Small Apertures, in: *Philosophical Magazine* 4 (4), 481-492.

Köhler, Christan (2019): Towards Sentinel 2 Based Environmental Contamination Monitoring, in: *Tagungsband 20. Geokinematischer Tag, 16. und 17 Mai 2019 in Freiberg*, 161-171.

Köppe, Julia (2022): Wir sprechen von einer relativ toten Zone, in: *SPIEGEL Wissenschaft*, https://www.spiegel.de/wissenschaft/druschba-pipeline-in-polen-wir-sprechen-von-einer-relativ-toten-zone-a-feef222e-ad6a-40f6-9073-28ea852a7dfc [27.07.2023].

Nico, Adam, Ralf Reulke & Volker Spreckels (2020): Neues Normungsverfahren „InSAR -Radarinterferometrie für die Bodenbewegungserfassung“, in: Thomas P. Kersten (Hrsg.), *40.Wissenschaftlich-Technische Jahrestagung der DGPF, 4.-6. März 2020 in Stuttgart*, 87-98.

OGE - Open Grid Europe (2020): CHARM(R) - lasergestützte Gasferndetektion - Effiziente und zuverlässige Leitungsprüfung aus der Luft. Präsentation, 4, https://oge.net/_Resources/Persistent/f/f/3/c/ff3c87769c0d9be48a2f712911d1adbc6f86f14c/20200604_OGE_Broschuere_Charm_DEU_online.pdf [16.05.2024].

Pawlik, Marcin, Tobias Rudolph, Jörg Benndorf & Jan Blachowski (2021): Review of Vegetation Indices for Studies of Post-Mining Processes, in: *IOP Conference Series: Earth and Environmental Science* 942, 1-17.

Ralf, Bill (2023): *Grundlagen der Geo-Informationssysteme*, 7. Auflage, Heidelberg: Wichmann.

Rao, Y. Chalapathi, D.C Santhi Rani & P. Lavanya (2012): Monitoring and Protection of Oil and Gas Condition in Industrial Using Wireless Sensor Networks, in: *IJECCT* 2 (5), 213-218, https://www.researchgate.net/publication/281008710_Monitoring_and_Protection_of_Oil_and_Gas_Condition_in_Industrial_Using_Wireless_Sensor_Networks [17.05.2024].

Rudolph, Tobias, Peter Goerke-Mallet, Andre Homölle, Andreas Müterthies, Holger Perrevort, Sebastian Teuwsen, Carmen Tomlik & Chia-Hsiang Yang (2023): Öffentliche Beteiligung im Geomonitoring - Das Fallbeispiel aus dem Kavernenfeld Epe, in: *Markscheidewesen* 130 (1), 3-13.

Saaty, Thomas (1988): *Decision Making for Leaders - The Analytical Hierarchy Process for Decisions in a Complex World*, 4. Auflage, Pittsburgh: RWS Publications.

SAPOS®-HEPS (2023): Hochpräziser Echtzeit-Positionierungs-Service. Bezirksregierung Köln. https://www.bezreg-koeln.nrw.de/geobasis-nrw/produkte-und-dienste/raumbezug/satellitenpositionierungsdienst-sapos/sapos-heps [28.07.2023].

Toth, Charles & Boris Jutzi (2017): Plattformen und Sensoren für die Fernerkundung, in: Christian Heipke (Hrsg.), *Photogrammetrie und Fernerkundung*, Heidelberg, Berlin: Springer Spektrum, 29-64.

Umweltbundesamt (2022): *Die Treibhausgase*, https://www.umweltbundesamt.de/themen/klima-energie/klimaschutz-energiepolitik-in-deutschland/treibhausgas-emissionen/die-treibhausgase [27.07.2023].

WDR – Westdeutscher Rundfunk (2014): Wir wollen nichts Kleinreden – Sondersitzung zum Ölleck, https://www1.wdr.de/nachrichten/westfalen-lippe/gronauleck100.html [17.05.2024].

Yin, Xiaoxuan, Bodo Bernsdorf, Peter Goerke-Mallet & Tobias Rudolph (2022): Die „Muse" im nachbergbaulichen Geomonitoring – Neue Ansätze für das Poldermonitoring, in: *Markscheidewesen* 129 (1), 29-36.

Link to presentation

https://thga.sciebo.de/s/W5CT59cZNA6A7gh

Technische Hochschule Georg Agricola

Days of Security Research

Day 2: June 15th 2023

Session: Future Technologies Part 2

Private smart home systems as a building block in the ADLeR project - from convenience functions to a value-adding contribution to the population's ability to help themselves.

Oliver Krüger

Dortmund Fire Department

Summary

Smart home systems are becoming increasingly widespread in German private households and offer more and more functions for automating technical systems in everyday life. The primary aim is to increase efficiency, e.g. to reduce energy consumption or provide additional convenience. However, The Fire Brigade of Dortmund also sees great potential in these systems for increasing the level of safety. As part of the concept phase of the SifoLIFE project ADLeR (Automated Detection, Reporting and Control System - Rethinking the Rescue Chain), the needs of all user groups, the possible technical implementation and the expected impact were analysed. On this basis, an implementation concept was developed which, subject to further funding, can be realized and evaluated quickly to achieve the desired added value. As a result, people with limitations in their ability to rescue themselves in particular could benefit from an innovative rescue chain. Detection independent of an emergency call and technologically supported deployment processing should prevent time being lost in the provision of assistance, which for this target group means a much higher risk to life

Initial situation and analysis results

The ADLeR project aims to optimize a technical and organizational construct for providing assistance - the rescue chain (1) - using a specific technology - smart home systems (2) - to increase the level of safety, particularly for a target group - people with limited self-rescue capabilities (3). These three influencing factors have a significant impact on the solution presented later and were therefore analysed in detail at the beginning of the concept phase. The findings are presented below:

The rescue chains

The tasks of fire brigades and rescue services are regulated on a state-specific basis, e.g. in NRW in the Act on Fire Protection, Assistance and Disaster Control (BHKG) and in the Act on Rescue Services and Emergency Rescue and Patient Transport by Companies (Rettungsgesetz NRW - RettG NRW). In order to fulfil the tasks defined there, individual process steps are necessary, the technical and organizational linking of which is represented in the so-called rescue chain. The process starts with an incident that is noticed by those affected or eyewitnesses and reported to a fire service control centre using the emergency number 112. Only the eCall in the motor vehicle sector represents an automated and standardized alternative to this method of reporting according to the current state of technology. As a part of the call, a structured emergency call enquiry is typically made on the basis of which the dispatcher sends the appropriate units. These units are deployed and must reach the scene of the emergency before they carry out reconnaissance and development measures and continue with the handling of the operation.

Standardized processes as well as the continuously checked and, if necessary, extended availability of rescue resources in accordance with the rescue service requirement plans ensure that a response time of 8 minutes is achieved in large cities such as Dortmund, for example. The work of the dispatchers and emergency personnel on site is also typically fast and effective thanks to a high level of training and process optimization. This makes the influence of the time required for the only step that cannot currently be influenced by the BOS all the more critical. In many cases, the detection and reporting of an incident happens immediately, but in some situations it can cause a delay of several minutes to several hours. Furthermore, time may be lost if there are disruptions on the approach or if the number or intensity of necessary measures at the incident site must be increased due to the conditions prevailing there. In particular, finding the exact emergency location and making it accessible can take a considerable amount of time, depending on the type of building. As part of the investigation of established processes, a number of starting points were therefore identified whose technological optimization can not only increase the robustness of the rescue chain, but also shorten the necessary process times.

Smart Home System

"The term 'smart home' refers to a home that has been upgraded with information and sensor technology and is networked both internally and externally."[3] A recent study by Bitkom e.V. shows the significant increase in the use of smart home systems in Germany and the wide range of usage types.[4] While 26% of respondents stated that they used such devices and functions in 2018, this figure had risen to 43% by 2022. The systems can be configured modularly by installing the desired actuators or sensors in corresponding rooms and networking them directly with each other and/or a central computer unit. The use of cross-manufacturer connection standards such as matter is becoming increasingly popular in response to customer demand for interoperability.[5] As a result, a wide range of functionalities can be created, which currently cover the areas of energy (lighting and heating control) and security (alarm system and video surveillance) particularly frequently. Networked fire alarms are currently only used by 5% of respondents and the functionality of the home emergency call is only used by 3%.[6] An availability analysis of the technical components by ADLeR showed that the devices required to support the rescue chain are already market-ready and available. The needs-based programming of the software backend for direct networking with BOS structures and the promotion of use by the population were therefore defined as tasks to be solved.

---

[3] https://wirtschaftslexikon.gabler.de/definition/smart-home-54137/version-384532

[4] https://www.bitkom.org/Bitkom/Publikationen/Das-intelligente-Zuhause-Smart-Home-2022

[5] https://matter-smarthome.de/

[6] https://www.bitkom.org/Bitkom/Publikationen/Das-intelligente-Zuhause-Smart-Home-2022

People with limited self-rescue ability

People with limited self-rescue ability are in particular those who are unable to rescue themselves from the danger zone of an incident and have difficulty drawing attention to themselves or making a successful emergency call. Typically, there are risk factors for this when mobility and cognitive abilities are limited, meaning that older people and people with disabilities are often affected. However, even people of all ages who live alone may no longer be able to call for help themselves in an emergency.

Limitations in self-rescue capability were also identified as a danger for those affected and as a catalyst for weaknesses in BOS processes, particularly in the context of the current rescue chain. On the one hand, the rescue chain is largely based on an emergency call received by the control centre. If the person concerned is unconscious and alone, is unable to reach the telephone or cannot successfully make the emergency call, no further action can be taken. It must also be taken into account that people with limited self-rescue ability may not be able to leave danger zones, or only to a limited extent. Flames and smoke, as well as other hazards such as flooding, therefore have an earlier and/or greater impact on this group of people. As a result, any time lost in providing assistance will put the lives of these people in danger all the more quickly.

In addition to the logical connection between these factors, indicators were also identified in numerous statistics that point to a particular risk for this target group and therefore a need for action through ADLeR. For older people, an age limit of 60 years was set, which divides the German population into 70 % younger and 30 % older people. In contrast, there is a disproportionately high proportion of people over the age of 60 in the annual fire deaths (2020, 70 %), but also in the deaths from the 2021 flood (79 %). Furthermore, the medical emergencies at the example location of Dortmund are similarly clearly distributed towards the elderly, so that 64 % of all medical emergencies are attributable to people in the 60+ age group. Against the backdrop of advancing demographic change, the Dortmund fire service therefore sees a strong need for action, e.g. to optimize the rescue chain in an innovative way through the ADLeR project.

Solution concept

Based on the analysis of current processes and the needs of the target group, a solution concept was developed as part of the concept phase of the ADLeR project. This is based on the phases of the rescue chain (Figure 1) and is intended to create a higher level of safety through the innovative networking of established technical and organizational components of assistance.

Starting with detection and notification, the plan is for sensors in the home and in end devices worn on the body to automatically recognize emergencies. In addition to multi-criteria fire detectors, presence detectors and smart electricity meters, water detectors will also be used to recognize the ingress of flood water (Figure 2). To detect emergencies, the sensors permanently transmit data to a central computer in the home (known as a hub). A rule set of parameter limits and decisions is stored there, whereby an emergency can be identified from the data stream of one or more sensors in combination and an automated emergency call can then be made. The resident should be given a 20-second intervention period before the alarm is raised. In this way, false alarms are to be reduced during the development phase of the system through a deliberate but justifiable loss of time. The detection and signalling process is completely apartment-based, i.e. on the one hand no data is passed on to third parties during continuous operation, i.e. until an emergency occurs, and on the other hand rule sets can be set specifically and user-orientated for each hub. The emergency call is then transmitted directly to the control centre and includes all relevant information available that can be recorded by the sensors. In addition to the exact location of the flat (address and position in the building) and the reason for the emergency, more precise information can also be provided, such as whether and how many people are in the flat and in which rooms they are located.

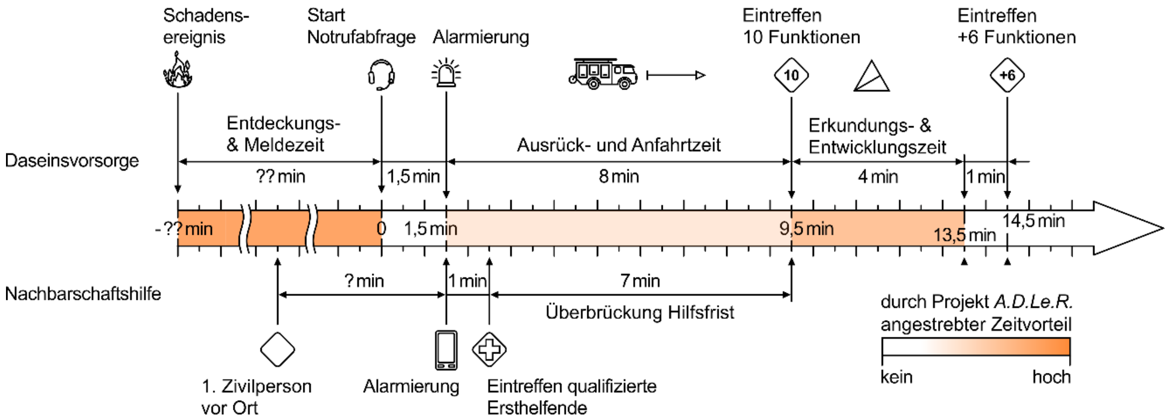


Figure 1 - Rescue chain with influence of the ADLeR concept (own illustration)

The next phase of the rescue chain to be changed by the ADLeR concept is the response and arrival time. Here, automated processes in the home, such as automatically switching off the cooker or other electrical appliances, can already help to ensure that a fire develops less violently by the time the emergency services arrive. Another solution component is the involvement of qualified first responders. These are part of an established organization and can be technically alerted by the fire service control centre via a dedicated app. Dispatchers at the control centre can see in advance whether and which first responders are available in the relevant vicinity of the emergency location and can use the available information from the housing system to decide whether the deployment is suitable for support. If the alarm is raised, relevant data for first responders can also be forwarded to the app via the control centre in order to improve the quality of the assistance provided and, if necessary, reduce the stress experienced by first responders due to a lack of information. In principle, the automated detection and reporting of emergencies should not only improve the work of public safety organizations, but it can also be assumed that the immediate recognition of emergencies will enable first responders, who typically provide immediate assistance, to be deployed in more cases. Finally, the time it takes for the emergency services to mobilize and arrive should not only be bridged by first responders, but also reliably kept as short as possible through technical measures. To this end, available lighting systems on the outside grounds of residential properties can be equipped with smart lamps and used as colored markers to indicate the arrival destination in the event of an emergency. Particularly in the case of nighttime operations, where delays can occur due to insufficient lighting of house numbers, for example, this enables a quick and direct approach on sight.

The final phase of the rescue chain, i.e. the investigation of the scene and the development of the operation, should also be supported. Here, the strategy of marking the route to the emergency flat with colored light is to be continued by using the doorbell system and the lighting in the hallway. In the event of an emergency, the latter will also be switched to permanently on to ensure that other residents can escape safely and that the emergency services can carry out their work easily and safely. Another core component of this phase is the electronic door lock. These are to be used both for the front door and for flat doors and allow emergency services and, if necessary, first responders access via a numerical code, which is communicated via the control centre. This enables first responders to gain access to the emergency location without delay and emergency services to provide assistance much more quickly. Other actuator components of the home systems can also include self-opening shutters and acoustic systems in neighbouring flats, which are then alerted to the emergency. To summarize, the emergency location is to be equipped as an active helper in dealing with emergencies. The corresponding measures run automatically in the background in order to actually achieve optimization in the form of safety and time gains without creating additional tasks or interaction with further technology by the emergency services.

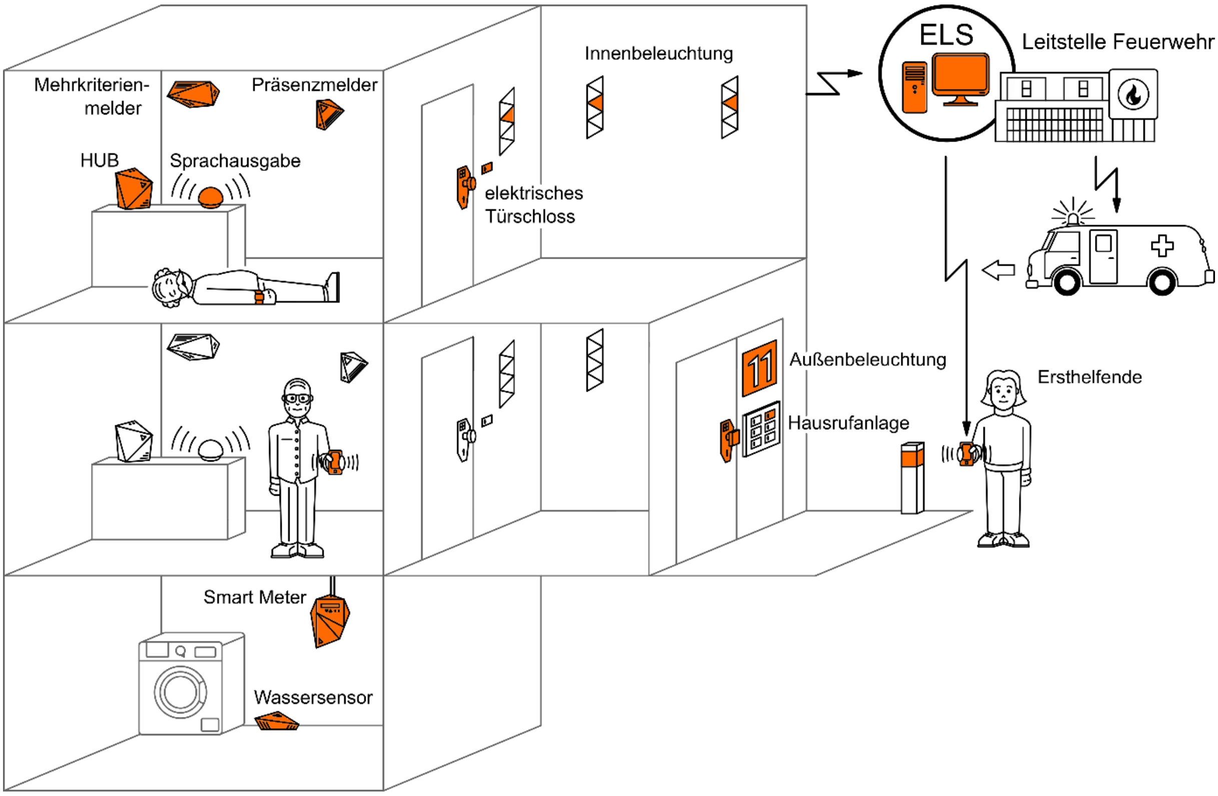


Figure 2 - Technical system components of the ADLeR concept (own illustration)

In addition to the technical system integration of the ADLeR concept into the rescue chain to increase safety, this innovation must also be integrated socio-technically and economically into the everyday lives of all user groups. Interaction with the system should be as simple as possible for the residents of the respective residential unit, also in view of the main target group identified. Accordingly, the system is designed in such a way that hardly any interaction is required for continuous operation once the standard set has been set up with support if necessary. In order to address possible limitations in sensory perception, the use of app-based operation and a voice assistant are also planned. Furthermore, the technical installation and initial use of the ADLeR project will be accompanied by intensive education and information measures to make the system and its functions comprehensible. This is the only way to achieve a perceived increase in safety and thus make a positive contribution to users' self-determined everyday lives. At the same time, the ADLeR concept provides for a multi-perspective financing concept. This is because although smart home systems are only considered too expensive by 29% of non-users as market penetration increases[7], retrofitting a home can cost several thousand euros. However, lower-income households should by no means be excluded from improvements to the level of security. It is therefore planned that housing associations, insurance companies and, where appropriate, public bodies will contribute to the costs together with the users. As the direct combating of incidents typically results in less financial damage as well as saving lives, the first-mentioned institutions can be incentivized to pass on their own savings proportionately in the form of subsidies for use.

Discussion and Outlook

The ADLeR project currently comprises an overall concept based on needs and solution approaches to improve the level of safety in everyday life, especially for people with limited self-rescue ability. This includes the integration of innovative technologies and additional assistance measures into the existing rescue chain in a way that generates comprehensive technical-organizational as well as socio-technical and economic implications. Accordingly, practical testing of the concept is necessary. The first step is to determine the measurable safety gain from the perspective of the BOS, but also the perceived increase in the quality of life of the users. These benefits must then be put into context with all the costs and possible hurdles involved in introducing and using the system in order to be able to make a final statement on the achievement of objectives and ultimately the usefulness of all measures. In addition to the holistic analysis of the system, the contribution of individual components of the smart home systems will be evaluated. This should result in a recommendation for the compilation of the systems by private users, as they are responsible for the future design beyond the scope of the project. Comprehensive usage analyses must also be carried out for the networking of private technology with BOS systems. These are to be prepared in action guidelines for other fire services and BOS in order to promote the transferability of the concept developed in Dortmund to other areas. In conclusion, it can be stated that the expected added value of the ADleR concept must first be practically tested and evaluated on a small scale. If the results of these tests and further developments are positive, these added values should be presented in detail and widespread use should be promoted among private users and politicians. While BOS and the population would benefit equally from the nationwide integration of smart home systems into the rescue chain, scaling is primarily the responsibility of market interest and the population. The potential for increasing utilization exists, only the new functionality in accordance with the ADLeR concept needs to be established. To drive this process forward on a supra-regional scale, it is estimated that it will take 5 to 10 years after the local demonstration has been completed.

[7] https://www.bitkom.org/Bitkom/Publikationen/Das-intelligente-Zuhause-Smart-Home-2022

Literature

Bitkom (2022): Das intelligente Zuhause: Smart Home 2022. Ein Bitkom-Studienbericht. September 2022, https://www.bitkom.org/Bitkom/Publikationen/Das-intelligente-Zuhause-Smart-Home-2022 [23.05.2024].

BMK – Bundesministerium Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (o.J.): eCall – der automatische Fahrzeugnotrufdienst, https://www.bmk.gv.at/themen/verkehr/strasse/verkehrssicherheit/unfaelle/ecall.html [23.05.2024].

Destatis – Statistisches Bundesamt (2023): Bevölkerung nach Altersgruppen, https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bevoelkerung/Bevoelkerungsstand/Tabellen/bevoelkerung-altersgruppen-deutschland.html [23.05.2024].

DKKV – Deutsches Komitee Katastrophenvorsorge e.V. (2022): Opfer- und Schadensdaten zur Flut 2021 in Rheinland-Pfalz. DKKV Datenaufbereitung auf Basis der Daten der Aufsichts- und Dienstleistungsdirektion (ADD) Rheinland-Pfalz sowie vom Landesamt für Soziales, Jugend und Versorgung Rheinland-Pfalz (LSJV - RLP), https://dkkv.org/wp-content/uploads/2023/02/Anfrage_Opfer-_und_Schadensdaten_der_Flut_2021.pdf [23.05.2024].

Feuerwehr Dortmund: Einsatzstatistik Feuerwehr Dortmund, Zeitraum: 06/2020 bis 06/2021.

Gabler Wirtschaftslexikon (o.J.): Definition: Was ist "Smart Home"?, https://wirtschaftslexikon.gabler.de/definition/smart-home-54137/version-384532 [23.05.2024].

DIGITAL-ROOM (o.J.): matter-smarthome. Die unabhängige Info-Seite zum Smarthome-Standard Matter, https://matter-smarthome.de/ [23.05.2024].

RECHT.NRW.DE (2024a): Gesetz über den Brandschutz, die Hilfeleistung und den Katastrophenschutz (BHKG), https://recht.nrw.de/lmi/owa/br_text_anzeigen?v_id=61120160624160758031 [23.05.2024].

RECHT.NRW.DE (2024b): Gesetz über den Rettungsdienst sowie die Notfallrettung und den Krankentransport durch Unternehmer (Rettungsgesetz NRW - RettG NRW), https://recht.nrw.de/lmi/owa/br_text_anzeigen?v_id=10000000000000000325#:~:text=(1)%20Die%20Kreise%20und%20kreisfreien,Rettungsdienst%20und%20des%20Krankentransports%20sicherzustellen [23.05.2024].

Link to presentation

https://thga.sciebo.de/s/Fh7fTKLRDNUnhK3

KIWA - Artificial Intelligence for Flood Warning

Ralf Hedel[1], Patrick Brausewetter[1], Susanna Kunzmann[1], Jens Grundmann[2], Anette Eltner[2], André Kutscher[2], Tanja Morgenstern[2], Xabier Blanch Gorriz[2]

(1) Fraunhofer Institute for Traffic- and Infrastructure Systems

(2) Technical University Dresden

Summary

Flood events like those in 2002 and 2021 pose significant challenges to society. Early detection of emerging hazards and better data for decision support in managing such situations can significantly contribute to damage prevention or reduction. The BMBF-funded joint project KIWA develops a non-invasive, AI-based technology for automatic monitoring of watercourses using camera images. This technology enables automatic analysis of camera images and continuous determination of important water parameters. These water parameters are fed into precipitation-runoff simulations, which in turn enable detailed flood hazard forecasts and situation assessments. The measurement and forecast results are integrated into the digital command and control system MobiKat® to effectively support decision-makers in assessing the situation and analyzing possible actions. The goal is to effectively support decision-makers in assessing the situation and analyzing possible courses of action. The camera-based measurement method developed in the KIWA project already has very high accuracy under favorable observation conditions. In the further course of the project, particular emphasis is placed on the robustness of the measurement method.

Background and Introduction

The KIWA project aims to support emergency services and especially decision-makers in the detection, evaluation, and management of natural disasters, particularly heavy rainfall and flood events.

Predictions of precipitation amounts are often not precise in their temporal and spatial distribution, especially during heavy rainfall events. This particularly affects the catchment areas of smaller watercourses. On-site command centers require sufficient lead time to "get ahead of the situation" and to be able to assess and evaluate action options in a timely manner.

Advancements in scientific and technical areas such as camera sensors, image analysis algorithms, artificial intelligence frameworks, PC computing power, and mobile communication raise hopes that current watercourse parameters can be determined almost in real-time based on camera images, particularly water level height and flow velocity. This opens up the potential for developing a method for safe, non-invasive measurement of these water parameters. Using these continuously determined parameters and a pre-determined water profile, flow [m^3/s] can be estimated and used as input for discharge predictions.

The goal of the KIWA project is therefore to develop, demonstrate, and evaluate AI-based tools for flood warning and observation to support emergency management agencies in coping with major damage situations resulting from heavy rainfall and floods.

KIWA consortium partners include the TU Dresden, Chair of Hydrology (coordinator), the Junior Professorship of Geo-Sensor Systems, and, from Fraunhofer IVI, the Strategy & Optimization Department. Associated project partners are the State Flood Center of Saxony, the State Operating Company for Environment and Agriculture of the Free State of Saxony (BfUL), and the districts of Bautzen, Görlitz, and Saxon Switzerland-East Ore Mountains. The practical requirements for the demonstrator are surveyed with the project partners, and their implementation in the developed solution is continuously checked for acceptance. The contribution presents the project's achieved results and individual elements of the demonstrator.

The project aims to develop and demonstrate the following AI-based tools:

- AI for automated water level detection from camera images: The focus is on image classification to reliably distinguish between water surface and shore. By intersecting the selected water surface with a precise 3D terrain model, water level determinations or statements about water level differences are made possible. Higher accuracies are expected compared to existing image classification methods. For robust application, the AI needs to be trained even under difficult observation conditions (e.g., night, backlight, rain).
- AI for deriving flow rates for watercourses: The starting point is the image-based determination of surface velocities using particle tracking. By incorporating past measurements and watercourse characteristics, flow estimation is expected to be possible, even under challenging observation conditions.
- AI for simulating precipitation-runoff processes: The focus is on developing suitable network structures that describe the nonlinear behavior of catchment areas in transforming precipitation into runoff. Speed advantages are expected compared to previous deterministic hydrological modeling.

Data Sources

The KIWA project develops or uses three different types of measurement points:

Type A: long-term measurement gauges of the associated partner BfUL - these are gauge stations in the official measurement network for which long-term water level and flow measurements already exist. In KIWA, they are additionally equipped with optical camera systems and, if necessary, with IR illuminators. In the project, the gauge locations Elbersdorf (on the Wesenitz), Großschönau (Mandau), and Lauenstein (Müglitz) are used.

Type B: flood cameras of the project partner Fraunhofer IVI - Fraunhofer IVI has been equipping flood-prone watercourses with camera systems since 2011. These are equipped with additional measurement systems for water level measurement (pressure probe, radar) in KIWA and used for method application. Particularly relevant camera locations in the project are: Heidenau (Müglitz), Zittau (Neiße), Neukirch (Wesenitz), and Großröhrsdorf (Große Röder).

Type C: mobile, autonomous flood cameras KIWA - they serve for method transfer, monitoring of previously unobserved locations, and testing of new deployment scenarios. The primary deployment scenario is the ad-hoc monitoring of watercourses during emerging heavy rainfall or flood situations. In addition, other scenarios could be covered, such as monitoring water retention basins. For deployment, the mobile camera systems are to be transported and set up at suitable observation positions by personnel or members of the fire brigade or civil protection. The mobile measurement cameras should be able to operate independently of external power supply for at least three days - with solar panels permanently or autonomously for about 10 days. The goal of the design is to minimize the involvement of emergency services for setup, configuration, and maintenance of the camera systems. The mobile systems consist of three main components:

(1) The KIWA system case with dual-SIM 4G/5G network router and MIMO antennas for redundant mobile network connection, a powerful industrial PC or notebook for local execution of the AIs, a data storage (NAS) for archiving camera images and video clips, as well as power supplies/PoE injectors for the camera etc.,

(2) The power supply in the form of a Li-ion battery with integrated battery management system, inverter, charge controller, and mains filter, and optional solar panels to extend the autonomous operating time,

(3) A PTZ (Pan-Tilt-Zoom) network camera with infrared illuminator on a stable telescopic stand with anchoring options on the ground.

In addition, the exact georeferenced 3D model is collected from each location, and the internal geometry of the cameras is determined by taking test images. This step is currently necessary for precise water level detection; however, with the increasing availability of highly precise comprehensive terrain models and the application of automatic compensation methods, these preliminary steps could be eliminated in the future.

Methodology for Estimating Water Parameters and Forecasts

For the determination of water level, the water surfaces were initially detected through AI-based automatic segmentation of the camera images using the AiSeg - Easy Pytorch Segmentation Toolbox (Wagner et al. 2023). The AI was trained to recognize water surfaces using approximately 1,100 different images where the water surfaces were manually marked. The training dataset consisted of only about 5% of images from KIWA camera locations, while the remaining 95% of training images were from other locations. The best performance in segmentation was demonstrated by the Convolutional Neural Network (CNN) UPerNet + ResNeXt50. CNNs are among the most important methodological approaches in machine learning today, particularly suitable for analyzing raster data images. A detailed exposition and systematic comparison of various model variants in practical applications for water surface detection can be found in the aforementioned publication by Wagner et al. (2023). By utilizing a digital terrain model (DTM) and the known camera orientation, the water level can be inferred from the water surface. Figure 1 visualizes the detected water surface on the left (in red) and the estimated water level on the right in conjunction with the DTM.

In the visualization, analysis and comparison of camera-based water level determination with official gauge data over the course of a year, it was revealed that while the camera-based approach fundamentally works, the water level is often either underestimated or overestimated. The discrepancy between the camera-based measurement and the reference water depth marker increased with longer measurement durations. This is attributed to the camera's lack of stability in its external orientation (position, viewing angle) and internal orientation (camera parameters like focal length) over time. Therefore, the stability of the external orientation was initially depicted and analyzed over time using static terrain control points. It became apparent that while there were minor fluctuations due to wind and temperature, there were also significant changes in the camera position and orientation, such as maintenance work or birds, among others. Within the project, an algorithm was developed to correct the calculations of all measurements based on the recognized positions of control points in the image. Consequently, the agreement between the camera-based measurement and the reference measurement at the water depth marker was significantly improved.

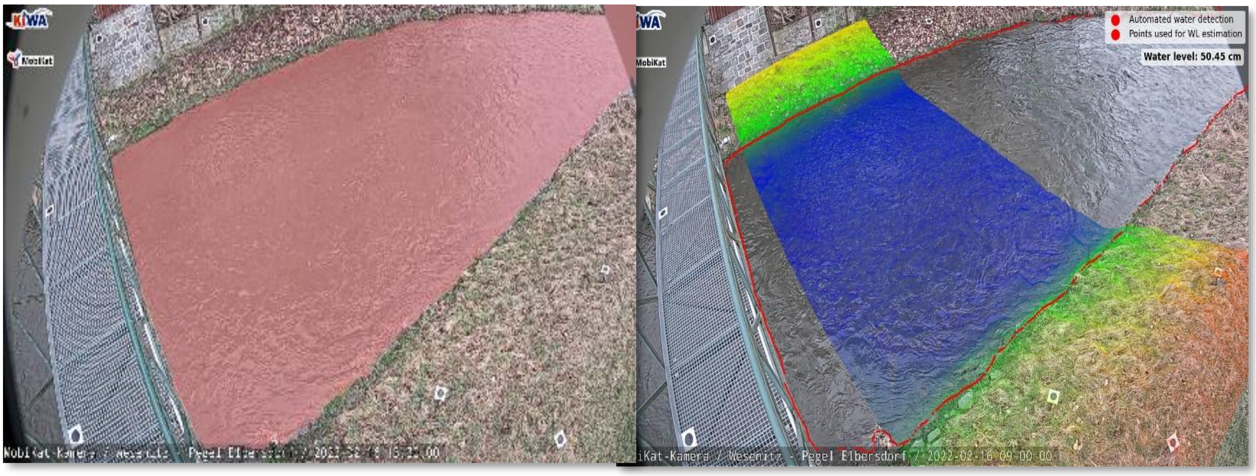


Figure 1: Optical water level measurement: (left) AI-based detection of the water surface, (right) estimation of the water level.

The determination of surface velocity uses the particle tracking method based on the implementation in the FlowVelo toolbox (Eltner et al. 2020). The workflow comprises the following steps:

1. Particle detection: All possible particles of a certain brightness are detected on the water surface in the first frame of a video sequence.
2. Tracking: All detected particles are tracked from frame to frame in the video clip, and their movement is recorded.
3. Filtering: Particles moving too fast, too slow, or in the wrong direction are filtered out.
4. Transformation: Conversion of the results from image space to object space using camera orientation, water level and the 3D model.

The accuracy of velocity determination depends on the number of particle measurements and the particle distribution. In the case of increased flow rates when many particles are entrained, the accuracy is significantly higher than at lower flow rates. At lower flow rates, there tend to be fewer particles that are poorly distributed and often influenced by local conditions such as weed growth. Consequently, the camera-based determination of surface flow velocity and resulting discharge becomes less accurate.

To further reduce errors or outliers, the OptiQ method (Kutscher et al. 2023) was developed and implemented by TU Dresden for determining continuous discharge time series with the following steps. The method is based on the velocity surface method (DIN EN ISO 748:2022-12) and is based on the subdivision of the watercourse cross section into containers or sub-areas:

- Reduction of the evaluation area: Instead of evaluating the entire visible flow profile in the image, only a 2 m wide strip in the middle of the profile is considered.
- Directional filtering: After determining the prevailing main flow direction, all measurements deviating from the main flow direction (± a tolerance) are removed. This removes influences such as snow and waves.
- Velocity filtering: Outliers are removed within the containers or sub-areas.
- Averaging all measurements at the same water level and storing them in a database.
- Using the database to fill sporadic data gaps (if too few particles are detected).

Based on the cross-section of the watercourse and the velocity, the discharge time series can then be determined. The results of the camera-based discharge estimation using the method described above are already very good, with a root mean square error (RMSE) of 0.22 m^3/s at the Elbersdorf reference site. Within the project, further AI-based approaches are being developed and tested to further optimize the process.

Subsequently, a fine-scale forecast of the discharge for the next few hours is made. The KIWA project uses an LSTM (Long Short-Term Memory) network for this purpose. "LSTM" refers to the inner workings of the neurons: along the time dimension, the calculations of the neurons are performed in a loop, and internal states are carried along, which give the network a "consciousness" of temporal relationships between network input and output after training.

Essential input data are the observed rainfall and discharge over the past 48 hours. The output of the method is the predicted discharge for the subsequent 6 hours. The training was conducted with selected rainfall-discharge events from the period 2007 to 2021. In systematic experiments, various model variations were tested and evaluated. It became evident that regional network training (where the AI is trained on multiple catchment areas simultaneously) performs significantly better than training with the data from a single catchment area (Morgenstern et al. 2023). In regional network training, the network learns more hydrological events with a wider range and thus learns a more general hydrological behavior. As a result, the network can predict more accurately.

Figure 2 displays various quality measures for the different model variants. It becomes clear that the network trained without the data from the specific catchment area (orange line) forecasts future discharges significantly better, outperforming locally trained networks. In the further course of the project, it is planned to test and potentially improve the extrapolation capability to extreme flood events. Synthetic training datasets will be used for this purpose. Additionally, it is envisaged to assess attributes of catchment areas regarding their influence on forecast accuracy (e.g., area size, slope, land use, degree of sealing).

The project's objective is to provide measurement and forecast data for decision-makers in areas such as disaster control and firefighting.

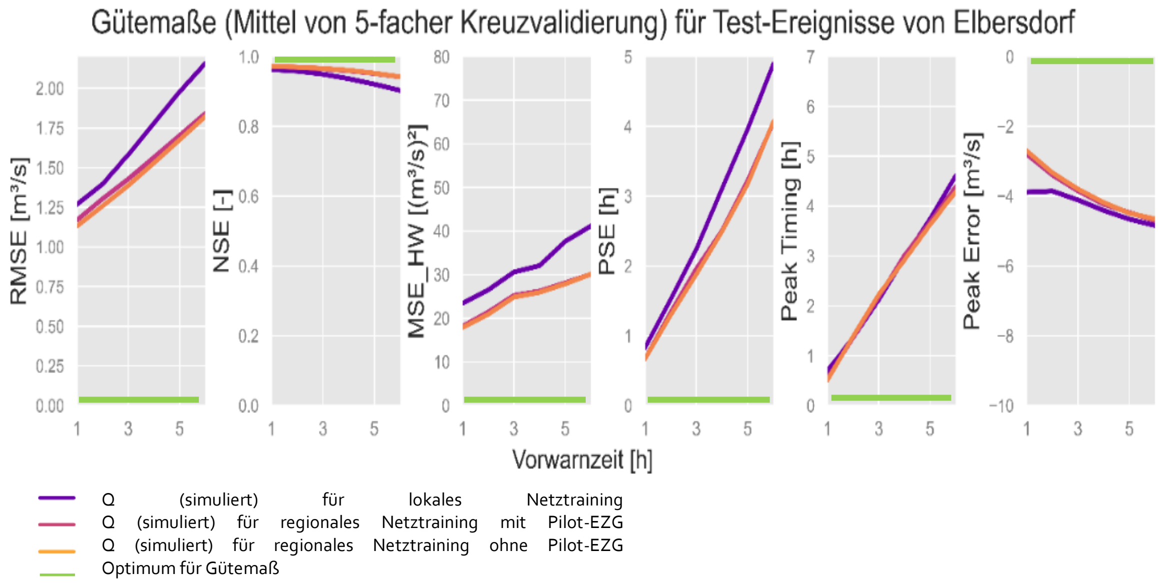


Figure 2: Quality measures of simulation network variants for the Elbersdorf site

In the context of bilateral consultations and workshops, functionalities and workflows were developed with associated end-users to effectively support situation management. These functionalities will be implemented and evaluated in both the Fraunhofer-MobiKat® camera dashboard and the Fraunhofer-MobiKat® command support system.

Figure 3 depicts the initial implementation in the Fraunhofer-MobiKat® camera dashboard. This is a web application that allows authorized individuals to access camera images and their history. In the site overview (top partial figure), future warning levels can be clearly visualized. In the detailed view (bottom), detailed measurement and forecast data for water level and discharge can be accessed directly for each location.

The Fraunhofer-MobiKat® command support system is primarily a desktop application designed to support situation analysis, assessment, management and documentation in particular. Situation data can be synchronized between MobiKat® instances via a situation server.

At the core of the system is a situation map that displays all operational measures, forces and resources, observations, protected objects, etc. Currently, only official water level values and flood inundation areas are visualized on the situation map. In the future, the measured values and forecasts at the camera-based KIWA measurement points will also be displayed on the location map using clear symbols. In addition to the live image from the respective water camera, measurement and forecast data can be accessed without system interruption. A slider can be used to display predicted flood areas of future time levels for different scenarios (probable - possible - unlikely) in the location map. The location data is intersected with flood areas. Clear statistics (e.g., affected residents, transportation, infrastructure, social facilities) are automatically generated and can be directly used or exported in the site management. Figure 4 visualizes an initial design aligned with end-users.

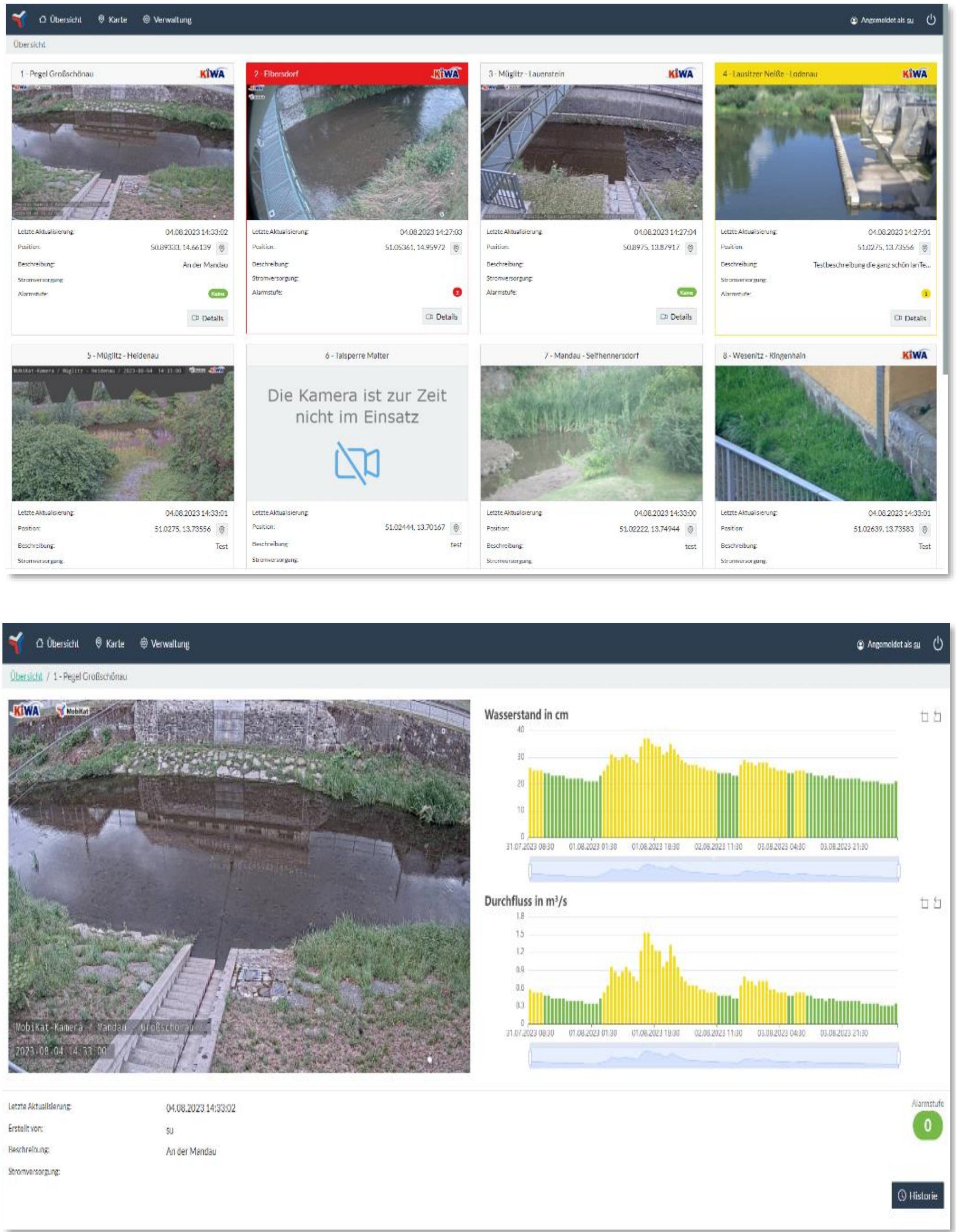


Figure 3: Web-based Fraunhofer-MobiKat® camera dashboard with enhanced measurement and forecast data.

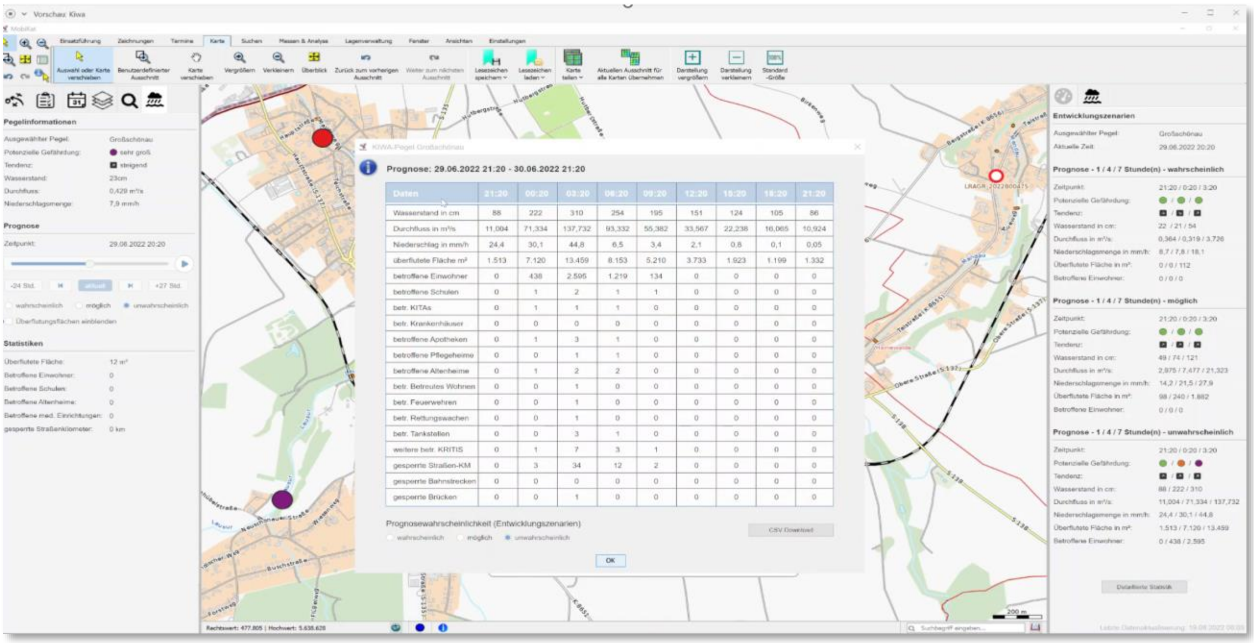


Figure 4: Intersection of forecast data with location information in the MobiKat® desktop system

Project Outlook

The key focus points for the remaining project term include:

- Training AI models for challenging observation conditions to make them even more robust, for example, in snow, backlighting and darkness.
- Method transfer to new locations: One sub-goal is to apply the methodology to camera locations that have not been precisely surveyed so far. For this purpose, it is necessary for the KIWA system to automatically determine the camera parameters.
- Automation and operationalization: Currently, individual AI models are still being developed or evaluated in an experimental setting, i.e., on individual computers of project team members as well as on virtual machines (VMs) in the High-Performance Computing Center (HPC) of TU Dresden. The consortium is currently working on integrating all components and providing them on a dedicated computer in the future. The idea is to deploy the AI models as close as possible to the cameras and not necessarily have to transmit camera images or video clips over the mobile network.
- Software enhancements to the Fraunhofer-MobiKat® camera dashboard and guidance support system.
- The realization of the mobile, self-sufficient measuring point of type C.
- The continuous evaluation, presentation, and improvement in collaboration with end-users.

Technische Hochschule Georg Agricola

Acknowledgment

The project results are only achievable with the support of the associated project partners. The project consortium thanks them for their tremendous dedication.

The KIWA project is funded by the Federal Ministry of Education and Research within the framework of the guideline "Artificial Intelligence in Civil Security Research II - Research for Civil Security 2018 - 2023".

Literature

DIN Deutsches Institut für Normung e. V. (2022): DIN EN ISO 748:2022-12, Hydrometrie - Durchflussmessung in offenen Gerinnen mittels Fließgeschwindigkeitsmessgeräten (ISO 748:2021).

Eltner, Anette, Hannes Sardemann, & Jens Grundmann (2020): Technical Note: Flow Velocity and Discharge Measurement in Rivers Using Terrestrial and Unmanned-Aerial-Vehicle Imagery, Hydrol. Earth Syst. Sci., 24, 1429–1445, https://doi.org/10.5194/hess-24-1429-2020.

Kutscher, Andre, Jens Grundmann, Anette Eltner, Xabier Blanch & Ralf Hedel (2023): Application of Optical Particle Tracking Velocimetry (PTV) to Determine Continuous Discharge Time Series, EGU General Assembly 2023, https://doi.org/10.5194/egusphere-egu23-9946.

Morgenstern, Tanja, Jens Grundmann, & Niels Schuetze, (2023): Flood Forecasting with Deep Learning LSTM Networks: Local vs. Regional Network Training Based on Hourly Data, EGU General Assembly 2023, https://doi.org/10.5194/egusphere-egu23-9726.

Wagner, Franz, Anette Eltner, Hans-Gerd Maas, (2023):): River Water Segmentation in Surveillance Camera Images: A Comparative Study of Offline and Online Augmentation Using 32 CNNs, International Journal of Applied Earth Observation and Geoinformation, Volume 119, https://doi.org/10.1016/j.jag.2023.103305.

Link to presentation

https://thga.sciebo.de/s/55eJlL6CDISON9O

Days of Security Research

Day 2: June 15th 2023

Session: Current Challanges

Integration of Spontaneous Helpers as a Key to Disaster Management?!

Michael Bartz

Privat

Abstract

Authorities and organizations with security tasks (BOS) are still unsure how to deal with spontaneous helpers. As the population's willingness to help has grown, the question arises as to how joint action among the stakeholders can succeed. In a study conducted in 2022, the cooperation between authorities and spontaneous helpers was examined using the example of the 2021 flood disaster in Stolberg (Rhld.). Based on interviews, it became clear that communication with each other plays a central role. In addition, the desire for central contact and collection points as well as fixed contact persons on the part of the authorities was expressed. Even if the support of the BOS is necessary from the point of view of spontaneous helpers, the focus of spontaneous helpers is still on acting independently in order to manage the situation unbureaucratically (cf. Bartz, 2024).

Introduction

In the night from July 14 to 15, 2021, storm Bernd caused catastrophic effects in parts of North Rhine-Westphalia (NRW) and Rhineland-Palatinate. The town of Stolberg in the southern part of NRW in the Aachen city region was severely affected by flooding due to persistent rainfall and heavy rain. The masses of water with up to approx. 240 l/m² in 24 hours led to flooding in a short space of time. Smaller streams and rivers such as the Vichtbach and the Inde turned into raging torrents. As a result, countless cases of property damage were caused to private and public buildings along the Vichtbach, particularly in the districts of Zweifall, Vicht, Atsch and in the city center (MULNV, 2021). In addition to emergency services such as the fire department and the Federal Agency for Technical Relief (THW), numerous private individuals, hereinafter referred to as "spontaneous helpers", stepped in to deal with the disaster on site.

The system for protecting the population in Germany is based on volunteer and full-time emergency personnel in aid organizations. In times of crisis and disaster, it has been shown that in addition to the deployed BOS forces, the willingness of the population to help in the form of independent and spontaneous helpers is growing. The flood disaster in 2021 made it clear that the help of spontaneous helpers is even necessary, as the capacities of state helpers are not sufficient. The BOS has already seen this contribution from the population in past events such as the Oder flood in 1997, the Danube/Elbe flood in 2013 and the refugee crisis in 2015 (Riebe et al., 2019; Uni Stuttgart, 2018c).

However, this willingness to help, which is desirable from the population's point of view, can lead to problems with regard to the actions of the state authorities and their aid workers. Spontaneous helpers, some of whom travel from all over Germany to help on site, lack leadership skills and coordination. It has been shown that, in addition to general disaster tourism, roads and access routes are blocked, for example, by parked cars of volunteers or are so narrowed that emergency vehicles of the fire department, THW or other aid organizations, such as the German Red Cross (DRK) or Malteser Hilfsdienst (MHD), have no free passage (IM NRW, 2022). This can hinder the saving of human lives or the prevention of danger. An overview of prioritized and urgent assistance at certain locations and objects is not visible to helpers when they arrive, so that measures may be taken where the time aspect plays a lesser role.

From the perspective of the BOS, there is a lack of clarity as to which activities spontaneous helpers could be used for (ibid.). The following questions arise in this context: What contact is desired, what support and resources are required and how can spontaneous helpers and the authorities work together? Uncertainty and a lack of information mean that the available potential in the form of spontaneous helpers is not fully utilized. This can lead to resentment and annoyance on the part of the helpers. There is often a lack of mutual understanding between spontaneous helpers and authorities, which can lead to conflicts (Riebe et al., 2019). There is also sometimes a lack of knowledge about the processes and working methods of all those involved (Betke et al., 2017). The main problem with coordination by the BOS is that the number of helpers and where and when they work are unknown variables. It is therefore necessary to create standardized structures and guidelines for cooperation between state authorities and spontaneous helpers (Kircher, 2014).

State of Research

Over the last ten years, numerous research projects have been initiated and carried out on the topic of spontaneous helpers. Examples include the ENSURE, KUBAS, KOKOS, REBEKA and WUKAS projects (see Kaczmarek and Diederichs, 2016; University of Halle, 2020; Rusch et al, 2019; Drews, 2019; Winter and Brückner, 2022).
The research projects explored different approaches and topics, such as occupational health and safety and technical solutions in the form of apps or similar. A holistic approach that can be used to combine the individual aspects and projects and serve as an overall system does not yet exist (as of 2022). Guidance for BOS, taking into account the needs of spontaneous responders based on past events, is only available in isolated cases as a result of the aforementioned projects. According to literature and internet research, an adapted or updated action guide based on the 2021 flood event does not yet exist.

Research Question

As part of the research work, the measures required to establish cooperation between the authorities and spontaneous helpers were investigated. On the one hand, the aim was to identify the motives, motivations and individual ideas of spontaneous helpers in relation to their actions. Secondly, it was analyzed what role state authorities can play and what support is expected from spontaneous helpers. In order to achieve this objective, the following sub-questions were examined:

- What criteria do spontaneous helpers use to decide whether, when and where to help?
- What support do spontaneous helpers expect from state authorities?

- How can mutual contact be established to coordinate assistance?
- Are social networks such as Facebook and Instagram for bundling and coordinating help the focus of spontaneous helpers or are official coordination centers, e.g. a telephone hotline, desired?
- What factors influence cooperation with state authorities and among spontaneous helpers themselves?
- What measures and actions are required in the run-up to a disaster in order to promote mutual understanding and coordination?

Method

In the study, qualitative interviews were conducted in the period from June 15, 2022 to July 31, 2022. Eleven people were selected as interviewees who were in charge of the flood response in the city of Stolberg (Rhld.) from July 14, 2021 to September 30, 2021. The number of respondents does not correspond to a representative sample because the focus was on selecting individuals who took on a leading or leading role in a spontaneous aid group (e.g. citizens' initiative, association or neighborhood community). A minimum age of 18 years was defined as a further inclusion criterion. A detailed selection according to characteristics such as gender, nationality, maximum age, profession and social status was not made. Exclusion criteria were defined as falling below the minimum age and deviation from the aforementioned period of activity. The needs and influencing factors of spontaneous helpers were determined using the example of the 2021 flood disaster in Stolberg. The emergence, structure and organization of spontaneous aid groups with the help of social networks played a central role in the approach. The aim was to gain new interdisciplinary insights and optimization approaches for future cooperation between authorities/BOS and spontaneous helpers and to present these in an action guide for BOS task forces when dealing with spontaneous helpers (cf. Bartz, 2024).
The following main categories were defined as part of the evaluation of the results:

- Criteria and influencing factors for spontaneous assistance (HK1)
- Communication (HK2)
- Authorities/BOS (HK3)
- Organization and coordination of spontaneous helpers (HK4)

Results

The results of the interviews conducted are presented below, organized according to the four main categories.

Criteria and influencing factors for spontaneous assistance

HK1, criteria and influencing factors for spontaneous help, includes all statements that provide information about the influences and criteria that lead spontaneous helpers to become involved. Reasons, motives and motivation play a central role in this context.
As an introduction to the interviews, questions were asked about the extent to which family members, friends, acquaintances and the interviewee themselves were affected by the flood disaster. Ten of the eleven interviewees stated that they had not been directly affected, as they either live at higher altitudes or in districts that were not affected by the event. All interviewees answered yes to the question of friends and acquaintances being affected.
When asked about the reasons for helping and the criteria on which the decision was based, it was reported that the disaster was "right on their doorstep" (I1, B2) and that they were therefore affected themselves. For some of the interviewees, the images that were spread via social networks and WhatsApp alone were enough to prompt them to go and offer their help. It became clear that it was not only the need of those affected that was decisive for the help, but also the desire to help people out of this need. One interviewee attributed his motivation to the severity of the event. In addition to the pictures and photos, a Facebook video of the raging river had prompted him to say "I have to get down there" (I5, B8). Another interviewee, on the other hand, mentioned that she had felt the urge to help because of the impressions her husband had described as a member of the volunteer fire department. During the interviews, it became clear that the spontaneous helpers put their own needs aside when deciding to help. Two interviewees applied for leave or canceled it. One interviewee noted that the numerous pictures and videos on social media were also reasons for the help: "[...] Everyone somehow suddenly realized that the public sector couldn't do it" (I6, B11). She also reported that her perception was that many helpers in her area wanted to offer their help because of their professional experience. The temporary help was attributed to the many impressions and stressful situations that she had experienced through the spontaneous help. Furthermore, a weakness in the support provided to spontaneous helpers during and after their work was mentioned. One interviewee noted that their own private life had to take center stage again after a certain period of time: "We had a core team that worked together for months [...]. It was only a few months ago that many of them said to each other: 'That's enough now. We need to think about our private lives and do something for ourselves again'" (I3, B5). The interviewees reflected on their work afterwards and see the state structures as being responsible. One interviewee stated: "Actually, we shouldn't even exist [...]. What we have done is largely a public sector task, and not that of some people who do it on a voluntary basis" (I3, B4).

Summary of the results from the main category 1:

- Concern is seen as a reason for providing assistance
- Local reference plays a central role
- Own needs are put on the back burner
- Perception and action are influenced by social networks

Communication

Statements that provide information about communication during the disaster were assigned to HK2.
In addition to personal contact on site and by phone (call/text message), the respondents mainly used social media to obtain information, organize and coordinate other spontaneous helpers. The

Facebook platform in particular was used by everyone. At the beginning of the disaster, either existing Facebook pages or groups were used or new ones were created for the occasion. Two interviewees used their existing initiative page, which had already gained a large number of followers due to the coronavirus pandemic. The rapid increase in awareness and the resulting reach were highlighted as advantages. As Facebook could not be used during the disaster in the affected area due to the unstable internet, the interviewees felt that switching to WhatsApp was the best option.
While the majority of respondents mentioned positive aspects, such as the high reach of the Facebook platform in the private sector, one respondent reported negative experiences in relation to calls from aid organizations: "Somehow there was a call to register as a volunteer with the German Red Cross. That didn't work at all. You couldn't call anyone. I wrote an email. I still haven't received any feedback on these things" (I5, B8).
Communication among the spontaneous helpers took the form of personal dialog as well as exchanges on social networks.
In terms of communication and cooperation among the spontaneous helpers, the majority of respondents rated this as positive. One interviewee attributed the bond between the spontaneous helpers to the common cause: "It quickly became clear between a few people: Okay, we're similar. Even if we have completely different histories and behave differently in life [...]. They want something similar. You can work something out with them. And that actually happened very quickly. We were all in the same situation" (I3, B4). Another interviewee considers the success of the spontaneous helpers to be the fact that they responded quickly to requests on social networks and were constantly monitored. From the interviewee's point of view, the personal contact and addressing other helpers played a decisive role. In order to get in touch with other spontaneous helpers and those seeking help, the advantage of a central location was mentioned: "The fact that we were centrally visible at the old town hall meant that we were also a point of contact for an incredible number of people [...]" (I6, B10).
All interviewees considered communication between spontaneous responders and the BOS to be necessary and, in retrospect, capable of improvement. The survey revealed that no contact persons were known to the spontaneous helpers on the part of the authorities. The interviewees consider fixed contact persons and contact points to be useful: "It would have been really useful [...] that helpers could have contacted somewhere. I couldn't say to people who came from Hamburg or anywhere else: 'Go there now! That was difficult" (I1, B1). One interviewee saw an opportunity to recruit more helpers, particularly with regard to looking after spontaneous helpers from outside the city: "We had two people who asked me, from up north [...] whether we had accommodation [...]. They then went [...] to the Ahr valley, because that's where it was. I think we could have had even more help. That's the issue with communication with the town, which definitely didn't take place" (I3, B5). The interviewees criticized the fact that communication was one-sided and originated from the spontaneous helpers, which meant that they could not be integrated into the structure of an aid organization after registration. A need for optimization is seen in the technical equipment for communication between the two actors. One interviewee reported: "When people from the DRK or something like that came and said: 'I'm not allowed to use WhatsApp on my work cell phone. Of course, it sucks when basically everything happens via these messengers" (I2, B3). Communication between BOS and spontaneous helpers was also important for B11. He sees this as an advantage for managing relief measures: "I think a city or an organization, whether it's the city or the district, definitely needs contact with the people on site so that it can set up a portfolio for itself, they can do this, they can do that, they can do that, in order to

then possibly establish contacts again. So there has to be someone who does this kind of screening. Otherwise, there's a risk that something will degenerate [...]" (I6, B11).

Summary of the results from the main category 2:

- Social media at the heart of mobilizing and coordinating spontaneous helpers
- Cooperation among spontaneous helpers can be traced back to "common cause"
- Choosing the right approach when contacting spontaneous helpers
- Communication between authorities/BOS and spontaneous helpers could be improved
- Fixed contact persons for spontaneous helpers were mostly missing
- Spontaneous helpers see the use of WhatsApp or Facebook on BOS service cell phones as necessary for two-way communication
- Contact persons of the authority/BOS on site desired

Authorities/BOS

Interviewees' statements that provide information about the perception and presence of the authorities from the perspective of spontaneous helpers were assigned to category 3.
The interviewees saw little to no calls for help from the authorities. The spontaneous helpers would have liked the authorities to reveal that help was needed: "What I would like is for them to say: 'Help, we can't do it'" (I5, B8). This perception was further explained as follows: "We actually assumed that our work wasn't needed at that moment" (I3, B4).
The interviewees only received sporadic support during their work. It was difficult for the interviewees to find the right contact persons on the part of the authorities. They found that there were too many paths and hurdles before the help got to where it was needed. The interviewees stated that they were largely on their own at the beginning of the disaster and felt that they were on their own. The leadership function in the context of support is seen to be with the authorities: "That by day 2 or 3 at the latest [...] someone who knows about disaster control says: 'Okay, watch out, I'm here from the fire department [...], I'm now in a leadership function and I'm doing this together with you'. That you [...] are not completely up in the air" (I2, B3). In the view of the interviewees, local responsibility must be taken quickly so that spontaneous helpers are not left to their own devices: "This official responsibility needs to be with us more quickly [...]. So we were left completely alone with things, that's a fact. If we hadn't helped ourselves, it would have been a huge disaster" (I2, B3).
Instead of support from the authorities, it was noted that they tended to work against the help of the spontaneous helpers: "There was a lack of support from the city administration. They actually put more obstacles in the way of every helper than, in the end, I would say, they cooperated" (I3, B5). One interviewee noted that the authorities were overwhelmed during the disaster: "It's not as if the whole of Stolberg was destroyed [...]. It's four districts and the overload on all sides" (I2, B3). In general, the majority of respondents would like the following with regard to support from the BOS: "less bureaucracy, do more, act immediately" (I1, B1).

As part of the cooperation, the BOS are expected to approach the spontaneous helpers: "The authority should approach this initiative [...]" (I1, B1). One interviewee sees an advantage in the fact that spontaneous helpers can influence the structures of the BOS or supplement and support them: "The problem in the first few days was that people couldn't even get to the camps that the

DRK had set up. Because without a bus connection, without a car, without everything, you can't get there at all. And then it quickly became clear here [...]: Okay, we simply have to take over the logistics, from the camps directly into the city, and distribute the things here [...]. And then a good relationship of trust was built up relatively quickly with the people [...] at the DRK" (I3, B4). It is noted that the framework conditions must be discussed for cooperation between spontaneous helpers and BOS: "There must definitely be a guideline [...]. And there has to be a contact person. And you have to discuss with them: 'What can we do as an association? What experience do we have? Where can you get something from us?'" (I3, B5). Furthermore, the interviewees would like to see spontaneous helpers directly involved: "They could have involved us directly. They haven't done that yet" (I1, B1).

In the view of the interviewees, spontaneous helpers have sufficient knowledge to be equal partners in the coordination process due to their various professional experiences. The spontaneous helpers see the authorities as having more of an advisory role when dealing with spontaneous helpers and would like to continue to carry out coordination independently on site. Only two of the respondents would welcome coordination and the creation of framework conditions. In particular, the interviewees see the designation of contact persons, the allocation of contact points and hubs as well as the designation of parking areas for arriving spontaneous helpers as the responsibility of the authorities. The interviewees consider it useful to have guidelines or a guide for spontaneous helpers on how to cooperate with BOS. In addition, the interviewees named the following factors or criteria as the basis for cooperation with the authorities: sensitivity, honesty, trust, attentiveness and respect.

"We are all experienced people [...]. I even have three jobs behind me by now [...]. I'm a logistician. I'm a businesswoman. And I've also worked in the medical field. That you simply say: 'We're not idiots, there are people sitting there who have experience. We have a background. And that this is also recognized as support [...]. I've always had the feeling that they smile at you." (I3, B5).

Summary of the results from the main category 3:

- Desire for faster decisions and less bureaucracy
- Perception of the authority/BOS not recognizable from the perspective of the spontaneous helpers
- Early involvement by spontaneous helpers required
- Guidelines and aids for spontaneous helpers desired

Organization and coordination of spontaneous helpers

All statements that provide information about the cooperation among each other, the creation of structures, organization and coordination as well as the qualifications and activities of spontaneous helpers were assigned to HK4.

Mutual trust was named as the starting point for the joint activities of the spontaneous helpers: "We just have a certain relationship of trust with each other" (I6, B10). As B2 did not have certain possibilities for implementation in the initiative, he sought contact with other groups of helpers in order to facilitate the request for help together: "We didn't have the vehicles, we didn't have the manpower that other voluntary groups [...] had. Then I just went and said: 'Okay, we have the call for help, you have the logistics and the manpower, so let's pool it together'" (I1, B2).

In addition to the extensive cooperation among themselves, the interviewees also reported conflicts within the groups:
"There were already a lot of conflicts [...]. Not so much at the beginning. I'd say it was the leap of faith we took at the beginning, because everyone wanted the same thing at first. But when a few things settle in and develop, and above all when structures develop, then you always have a huge potential for conflict" (I3, B4).
In Stolberg, spontaneous helpers from all over Germany were deployed alongside locals. The interviewees had different perceptions of the cooperation:
"They wanted to be served. So a lot of people from out of town were overwhelmed when I told them to find something. They wanted to have someone to talk to, they wanted to get to work right away, because I've got eight more hours and then they'll go home again." (I6, B10)
The results revealed different approaches with regard to the development of a structure. The interviewees stated that they had developed a management structure quickly. While some interviewees set up a management or core team with friends, acquaintances and other spontaneous helpers, others drew on existing structures in the form of associations or initiatives from the village community. The latter had the advantage that certain networks and processes were already known and personal relationships existed, e.g. through joint association work. In order to be visible to other spontaneous helpers and people seeking help, in addition to setting up a line tent at a central location, special vests with labels were created. These structures, which came about by chance, were not initially visible in other parts of Stolberg: "There was a lot of chaos at the very beginning. Lots of people and nobody knew where to send them [...]. It actually became clear to us pretty quickly: we have to create a structure here" (I3, B5).
It was reported that it was crucial to provide a central point of contact for spontaneous helpers before their own supplies were available and specific tasks could be distributed. According to the interviewees, the tasks and activities that the spontaneous helpers carried out or fulfilled developed differently over the course of the project in terms of structure formation.
"They just set up the barbecue here. That's how it started. Then a coffee stand was added, then various tables [...] where relief supplies were distributed. And then it went pretty quickly." (I3, B4)
The interviewees stated that the focus was initially on clothing and food donations, but that this gradually shifted to, for example, donations of building materials or the construction of a makeshift daycare center due to specific requests and offers of help. The interviewees noted that, due to the increase in tasks and deliveries of relief supplies, the available space is crucial for the fulfillment of the activity and was often a problem. For the interviewees, it was important that the storage could be secured against theft on the one hand and protected against the effects of the weather on the other: "In heavy rain, for example, conventional pavilions and tents are inadequate compared to containers for storing goods such as food, detergents or generally products that are packaged in paper or cardboard" (I4, B6). One interviewee critically mentioned a disadvantage in connection with the uncontrolled growth of individual supply camps: "First there was one pavilion, then there were five pavilions [...]. And not the area for donations, but the area where their children played, so it was like a public festival for them. It would probably have been good to have some management or guidance or support from the city" (I6, B11).
Person B4 reported positively with regard to the creation of structures within the spontaneous support groups. It is more efficient to complete tasks with smaller groups. Further advantages in this context were the simplified communication structure and the promotion of individual responsibility of individual helpers. On the other hand, spontaneous helpers named the feeling of being

treated "from above" by the authorities as a danger in connection with a centralized structure (cf. I3, B4).

The interviewees reported that the activities were not carried out on the basis of guidelines. According to person B2, contact persons on the part of the BOS had to be identified independently and the necessary personnel and materials had to be organized themselves.

"So that would have been good, [...] a folder [...] where the first things with all the contacts of an official nature are in there and you don't have to look for everything yourself." (I2, B3)

According to the interviewees, the challenge was to provide work for the large number of spontaneous helpers. Person B3 mentioned that the more helpers had to be coordinated, the greater the pressure to function. The means of communication available for coordination reached their limits for B4.

"It was a great group dynamic [...]. We were also overwhelmed by people who wanted to do something [...]. When I made a call, I was sitting there with the WhatsApp group and I wanted to note who was available and when. And then it pinged so often that the chat kept scrolling down again." (I3, B4)

The interviews emphasize that the number of helpers within the group was not always known after a call via social networks. This meant that the spontaneous helpers were sometimes limited in their ability to help due to a lack of helpers. The reverse was also reported, leading to chaos: "It was [...] totally chaotic [...]. Suddenly there were six trucks from Düren with clothes that nobody needed at the time" (I5, B9). In some places, helpers had to be turned away and sent on because capacities were exhausted.

The interviewees were unanimous with regard to the employment of spontaneous helpers. The distribution of tasks must be targeted, as otherwise there is a risk that helpers will be sent to places where no help is needed. "There's nothing worse than someone you want to send somewhere who has no work. He won't come back the next day." (I2, B3)

There were reports of helpers who had previously wanted to help in the neighboring town of Eschweiler, but wanted to move on and be deployed in Stolberg due to the lack of organization (cf. I2, B3).

Due to the provision of relief supplies and equipment, the interviewees were sometimes confronted with increased organization and coordination, so that cooperation and agreements between the respective camps were necessary.

"The people from the supply camp in Vicht [...] naturally tried to give us [...] everything possible [...]. That's how the structure worked. But that's also a village community. Everything was a bit more coordinated and a bit faster." (I3, B5).

With regard to organization and coordination, B5 noted that the camps in the city districts were better positioned than inner-city camps due to the existing village community. Based on the statements of the interviewees, it became clear that the choice of contact points and camps is crucial for success. B8 gave an example of how crucial this can be for those affected: "Then we had a donation hall up there and everyone was wondering where the people were all the time. At some point I said: 'People aren't coming up here' [...]. Firstly, they don't have the strength to walk up this mountain, and secondly, they don't have time because the world has ended down there" (I5, B8).

The interviewees did not perceive any control or coordination by the authorities during their period of activity. On the contrary: B9 emphasized the independent organization in the Stolberg districts of Vicht and Zweifall by spontaneous helpers (cf. I5, B9). According to B11, the authorities also did not take the opportunity to coordinate the spontaneous helpers (cf. I6, B11).

The interviewees stated that the first tasks performed as part of the relief effort were event-related tasks such as clearing mud, distributing food and sorting clothing donations. Spontaneous helpers also supported the aid organizations, e.g. by setting up camp beds. The interviewees noted that the activities carried out did not require any previous experience, so that anyone who wanted to help could be deployed directly. Older people, for example, took over the distribution of food at the supply point for those affected and spontaneous helpers.
"These were not tasks [...] that would have required any previous education or training, but it was: 'Put the box together, tape it shut and then put the bin liner in'. And anyone could do that." (I6, B10)
The spontaneous helpers also contributed skills and knowledge from their private and professional lives. They also provided private vehicles for transporting food, for example.

Summary of the results from the main category 4:

- Common goal of spontaneous helpers promotes cooperation among each other
- Structures of spontaneous helpers comparable to those of the BOS
- Management and coordination by BOS not recognizable for spontaneous helpers
- High willingness to help pushes spontaneous aid groups to their limits
- Activities could mostly be carried out without prior knowledge
- Spontaneous helpers bring a wealth of experience and knowledge from their professional and private lives

Discussion

In this chapter, the results are interpreted and discussed in relation to the previous theory and the research questions. Limitations of the study are highlighted and recommendations for further research are made.

Criteria and influencing factors with regard to spontaneous assistance

The results for HK1 showed that the respondents all had a personal connection to the damaged area. This became clear from the extent to which family members, friends and acquaintances were affected. The willingness to help was also triggered by the general concern that people in the respondents' own city and in the immediate vicinity had suffered hardship. Batson (1991, 2003) and Schwartz and Howard (1981) were already able to show that people act altruistically and pro-socially. The survey results of Fathi et al. (2016) from 2015 also correspond to those of the present survey with regard to inner values and the need to help people in one's own city or community. It was shown that the respondents who had not suffered any damage as a result of the event nevertheless developed the feeling of being affected themselves. This feeling can be traced back to the local connection to home. This feeling was reinforced among the interviewees by the impressions that were shared in personal conversations and via social channels. This not only influenced their perceptions and behavior, but also made the interviewees aware that the BOS alone cannot complete the tasks and work required in the necessary time. The interviewees realized for the first time through this event that the civil protection system in Germany has gaps

and/or limits in the event of disasters and crises, so that both self-help and external help from the population are essential.
The survey also revealed that people who are willing to provide help on a voluntary and honorary basis only have limited opportunities in terms of time and that psychological factors resulting from the experience must also be taken into account. Spontaneous helpers are also unsure about what options are available, e.g. time off work from their employer. The desire was expressed to create a clear legal regulation for spontaneous helpers, as already exists for BOS staff. The interviewees also criticized the psychological and psychosocial support and aftercare for spontaneous helpers during the flood disaster. This problem has not yet been perceptibly implemented in practice or in the emergency response structures at municipal and district level. The introduction or expansion of structures in the area of psychosocial emergency care (PSNV) for spontaneous helpers is desirable and necessary in light of the results.

Communication

The results of HK2 show that the communication options are used individually and not uniformly. While the two platforms Facebook and Instagram were used, it turned out, contrary to previous assumptions (cf. Bledau et al., 2014), that the respondents did not use the Twitter platform to obtain information. They mainly used Facebook to obtain information and to coordinate and process offers and requests for help. Both existing and newly founded pages and groups saw a rapid increase in followers and members in the wake of the disaster. This development can be attributed to the increasing need for information among the population, which was also confirmed by the interviewees. The theoretical factors of scale, type of event and local reference were significant in this context. The advantage of already existing groups, e.g. due to the refugee crisis and the COVID-19 pandemic, is that a large number of potential helpers can be reached directly. This offers the BOS the advantage of creating a central information point at an early stage by establishing their own pages (e.g. via the Facebook page of the municipality or district) in order to improve the resource management of the BOS. Promoting these pages to the public is crucial for success in the event of an incident. During the flood disaster, it became clear that the potential of existing pages and platforms such as www.unwetter-hilfe.org was largely untapped due to their unfamiliarity. The results of the survey also indicate that the BOS need to provide the personnel capacity to operate the sites and process the inquiries and offers. It became clear in the survey that one aid organization has not yet responded and that no further contact has been made with spontaneous helpers after registering via their website.
In addition to the platforms mentioned above, the use of WhatsApp played a central role for the respondents, e.g. for the exchange between individual spontaneous helpers and groups as well as the creation of WhatsApp groups in order to make arrangements and coordination. The widespread popularity of this form of communication also surprised the interviewees. In this context, however, it should be noted that both spontaneous responders and BOS staff reported difficulties with regard to collaboration via this medium, as it turned out that the use of WhatsApp on official BOS mobile devices is not intended or even prohibited. A solution is therefore required to ensure communication between the parties involved. Implementation at the level of the crisis management team or the tactical incident command (TEL) on site would be conceivable and should be considered.
There were parallels to the BOS in terms of cooperation between the spontaneous helpers. Similar to the cooperation between individual aid organizations and authorities to bundle or distribute tasks or activities based on experience or personnel and technical possibilities (e.g. collapse and

localization at the THW or firefighting at the fire department), the spontaneous aid groups regularly exchanged information in order to bundle additional helpers, for example, or to provide equipment and materials that other groups did not have in stock.
The interviewees described the cooperation among the spontaneous helpers as harmonious and goal-oriented, which they attributed to the common cause and shared goals. The informal groups of spontaneous helpers developed a strong sense of togetherness, which is an essential characteristic for the continuation of the activities. The common goal of making a difference and working away was mentioned several times in the interviews. This demonstrates the system-oriented approach with the motivational orientation of purpose and problem solving, which is more attributable to formal groups (cf. Gukenbiehl, 1994). The assumption that the characteristics of structure formation between informal and formal groups can mix (ibid.) was confirmed by the results of the present study. The structure created by spontaneous support groups resulted in a rapid response time in terms of monitoring social networks and processing offers and requests for help. The networking of spontaneous helpers is another key feature that, from their point of view, puts them ahead of BOS. The personal connection and willingness to network and cooperate also play a decisive role. In the groups, it was customary to address each other on a first-name basis so as not to create any distance between the helpers and those affected. This form of address is also commonly used within the BOS. In order to promote cooperation between spontaneous helpers and BOS, a standardized language should be established. As described in the KOKOS project, contact and the initial reduction of distance can be ensured by intermediary organizations or specialist advisors or liaisons (see Zettl, 2018). Until this has been ensured, contact must be made by the BOS forces (e.g. fire department) on site. To this end, sensitization and approaches to dealing with spontaneous helpers must be included in the training and further education concepts of the BOS.
Based on the perceptions of the interviewees, it became clear that there is room for improvement in communication between the two parties. It became clear that contact persons on the part of the BOS are not recognizable for spontaneous helpers and that there was a lack of appropriate contact points, especially on site, which are, however, desired. While the helpers from their own catchment area were able to compensate for this shortcoming on their own and use their own momentum to ensure that the activities were carried out without cooperation with BOS, the interviewees consider this to be problematic and not expedient with regard to external helpers. Early designation and establishment of staging areas and assembly points or contact points for spontaneous helpers should be implemented for future disasters and to ensure cooperation by the BOS. Transparent and clear communication is required for integration into the structures of the BOS and to reduce momentum. Further information, e.g. on how to get there and where to park and stay overnight, must be communicated by the BOS via the relevant communication channels.

Authorities/BOS

Based on the results in HK3, it became clear that the spontaneous helpers were not aware of the presence of the authorities. Only appeals for donations from the town of Stolberg were registered via social networks. Open communication to the population that the situation could not be handled independently by the structures of the authorities/BOS would have been desirable from the perspective of the interviewees. The results indicate that this information would have enabled even more helpers from the population to be activated promptly. The results suggest that the assessments and perceptions of the authorities differed from those of the spontaneous helpers.

However, only assumptions can be made in this regard, as a separate analysis from the perspective of the authorities would be required to make meaningful statements, but this is not part of this study. It should be noted that early communication and the exchange of information between both parties could promote the start of work. This could prevent frustration and a lack of understanding on both sides. The importance of crisis communication on the part of the authorities/BOS became clear from the statements of the spontaneous responders, who drew comparisons with other areas, e.g. neighboring towns or the municipalities of Eschweiler and Roetgen as well as the Ahr valley, in connection with networking with each other and the presentation in the media.
On the part of the authority/BOS, contact persons should be identifiable who can be contacted. The interviewees also mentioned the problem of excessive demands on the authorities. They had the impression that "obstacles were put in their way" or that they had to act "on their own". Furthermore, the desire for less bureaucracy in the event of disasters became clear. In this respect, comparisons were also made with other affected areas such as the Ahr valley. There was a lack of support, e.g. through the provision of transport options such as vans or trucks. It is therefore necessary to examine the extent to which public authorities/BOS can provide this or whether the involvement of private companies in the form of framework agreements or usage agreements in disaster situations would be more expedient. In addition, information about the authorities' processes and procedures should be provided as part of risk communication, ideally before an event occurs, in order to create understanding. The content can, for example, be integrated into existing training concepts (e.g. first aid courses) or new formats (self-help courses and school lessons) in order to reach a broad section of the population.
The interviewees described the cooperation with authorities/BOS in different ways. With regard to cooperation with BOS, it became clear that the organizations communicate differently with the population and involve them. While cooperation with the fire department was described as effective, cooperation with organizations that are usually less present in everyday life, e.g. the THW or the Bundeswehr, was less successful. Whether this is due to the unfamiliar appearance of these organizations in the population or to their fundamental way of working cannot be conclusively clarified on the basis of the available results. At this point, a more in-depth examination of the organizational structures and working methods is required, but this is not part of this study. The interviewees described communication as a central aspect of cooperation with authorities/BOS. From the perspective of the spontaneous responders, leadership and coordination must come from the authorities/BOS. However, as the interviewees were not aware of this, they developed a momentum of their own. It should be emphasized that there was a feeling of work being passed on to the spontaneous helpers. In order to prevent this, a clear agreement among each other and a previously defined or coordinated catalog of activities, as developed as part of the REBEKA project, could be expedient. The majority of interviewees were of the opinion that contact for cooperation should be established by the authorities/BOS. It would therefore be expedient to deploy liaison officers, possibly through the involvement of intermediary organizations.
Based on the results relating to the willingness to coordinate through BOS, it has become clear that the respondents have different attitudes towards this. One possible explanation could be the limitation of their independent action and self-realization. The interviewees mentioned, for example, the lack of training and further training of managers on the part of the authorities/BOS in dealing with spontaneous helpers. Furthermore, there are doubts about the skills of employees in the authorities. However, the interviewees could imagine an advisory role for the authorities.

The interviewees named the appointment of contact persons, the definition and allocation of contact points and parking facilities as well as the provision of materials for on-site implementation as specific tasks. This would enable spontaneous helpers to work independently and have a contact person in the authorities in the event of problems or requests for support. The authorities or BOS should create a framework for possible coordination. From the point of view of spontaneous helpers, a guideline or action guide could prove useful for both sides. It has become clear that the spontaneous helpers, either through the flood disaster itself or through previous events such as the refugee crisis and the COVID-19 pandemic, have been able to gain a wealth of practical experience that they do not yet recognize on the part of the authorities for their work on the ground. This view, as well as their experiences on the ground, makes the spontaneous helpers doubt the competence of the authorities, which is why they are skeptical about comprehensive coordination, even though it is desired. Joint exercises, training and education could be helpful in reducing doubts and skepticism. The key elements mentioned by the interviewees, such as sensitivity, honesty, trust, attentiveness and respect, should also be reflected in the training and further education concepts of the emergency services and those responsible in the authorities. Furthermore, open questions relating to the legal framework (e.g. insurance cover and release from work by employers) should be answered in information brochures for spontaneous helpers and on the websites of the lower disaster control authorities. The results have shown that the actions of spontaneous helpers are influenced by these legal uncertainties, as the regulations are not known.

Organization and coordination of spontaneous helpers

The results of HK4 clearly show that cooperation among spontaneous helpers depends on the starting point. The interviewees mentioned the keyword "relying on each other". In this context, it should be emphasized that the spontaneous helpers gave each other a leap of faith in order to take up the joint activity and continue it up to a certain point. The emergence of conflicts can be explained by the duration of the activity and the consolidation of hierarchies within the spontaneous helper groups. This can be seen from the statement of one interviewee, whereby established structures ensured that the potential for conflict increased.

One finding from the present results is that the interviewees perceived the involvement of external spontaneous helpers as sometimes disruptive or aggravating compared to local spontaneous helpers. This perception could not be identified in the literature. Whether the willingness to provide assistance and the type and duration of assistance were influenced by this cannot be answered on the basis of the results. Further research is required in this area. However, the results show that, compared to local spontaneous helpers, non-local spontaneous helpers only provided assistance for a limited period of time and, from the respondents' point of view, were sometimes overburdened. In this context, it is reasonable to assume that this can be attributed to a lack of local knowledge and existing structures. Over-motivation on the part of individual helpers was also suspected. However, it also emerged that local spontaneous helpers sometimes felt threatened by attempts to interfere with the leadership and coordination of external spontaneous helpers. This could be a possible indicator of the strengthening of the sense of unity among the local spontaneous helpers described above.

It has also become clear that existing village communities and the involvement and participation of associations, clubs and their members are conducive to rapid assistance from the population. Networking and access to existing contacts and materials have proven to be advantages for the implementation of aid offers within the spontaneous aid groups. The interviewees described the constant exchange among themselves and the regular meetings at the level of the management teams in the supply camps as effective. This shows parallels to the situation briefings of the BOS. The establishment of separate areas (e.g. management tent) within the camps and the visibility of the management, e.g. through (functional-) vests, are also -similar to the structures of the BOS units. A decisive factor in the creation of structures is the early definition of meeting and contact points for spontaneous helpers. The interviewees reported that these were elementary before the tasks could be concretely organized and distributed to other spontaneous helpers and their own care developed. At this point, it becomes clear that the spontaneous helpers must first ensure their own food supply for a certain period of time before taking up their work. In this context, the wish was expressed that the BOS, which organize and set up the catering for their own forces in longer situations, should also supply the spontaneous helpers. This aspect needs to be taken into account when planning for disasters. However, the flood disaster in Stolberg also showed that the reverse is possible, as the catering for the BOS units in districts such as Stolberg-Vicht was ensured by voluntary donations from the population and the supply camps of the spontaneous helpers. Due to the medium to long-term involvement of spontaneous helpers and the unpredictable increase in relief supplies and helpers, the location and area selected must also be taken into account so that the work of the spontaneous helpers is not negatively affected. The task of the BOS is to provide support in the form of suitable storage capacity to protect the relief supplies from the weather, for example, as it has been shown that private pavilions and tents are not suitable for this purpose.

The communication structure also plays a significant role on the part of the spontaneous helpers. The results show that it is advantageous if tasks and activities are carried out in smaller groups, as the formation of sections and subsections simplifies communication with each other and promotes personal responsibility at the center of the assistance. This working method or approach could reduce the feeling that the BOS wants to delegate activities to the spontaneous responders. In addition, the central structure developed by the crisis team could be pushed into the background. It is reasonable to assume that the willingness to help will last longer in this way and that the tasks will be carried out to the end.

It turned out that the activities were not carried out on the basis of an existing guideline or action aid. Rather, it became clear that the interviewees were not aware of any concepts, guidelines or action aids, as they repeatedly expressed a desire for them. This shows that the research carried out on the topic of spontaneous helpers and the efforts to make the results visible to the population were not transported to the local level (cities and districts). The derivation or implementation of the research results in the structures of the respective cities and districts is also not recognizable on the basis of the available results. For this reason, a closer look should be taken. The resulting momentum and learning by doing could have been avoided or coordinated by involving the authorities and BOS at an early stage. It should also be emphasized that the spontaneous helpers' failed attempt to work together was due to the lack of local contacts and the lack of response to contact attempts. The authorities and BOS should therefore develop a strategy to implement the aforementioned aspects on site. For example, flyers with contact details for the emergency vehicles of the BOS and the establishment of information as part of crisis communication in social networks by the press offices should be promoted.

Even if the results show that the coordination of the large number of spontaneous helpers was successful due to previous experience from the private and professional sphere, the pressure on the respective management teams in the supply camps described above is not insignificant. It has been shown that the unpredictable rush of spontaneous helpers requires a structure to be set up quickly, as the willingness to help depends on successful coordination. Based on the statements of the interviewees, it became clear that arriving spontaneous helpers want to be provided with work. In addition to purely verbal communication on site, other means of communication (e.g. cell phones or radios) are useful for coordination. The problem described at the beginning, that the number of helpers arriving is unknown to the authorities or BOS, was also observed among the spontaneous aid groups. In particular, the calls in the social networks made the planning and implementation of tasks more difficult due to the uncertain number of helpers in the spontaneous aid groups. A feedback function for the calls via these networks, as is the case with alerting systems such as *GroupAlarm* and Alamos *aPager Pro* in the field of BOS, could be a first approach to determining the number of people helping. Alternatively, continuous monitoring of the responses under the respective post or call would be possible, but this would be time-consuming and require a lot of personnel. In addition, the distribution or deployment of spontaneous helpers via individual assembly points around or along the damage area would be expedient. In addition, the BOS, instructed spontaneous helpers or intermediary organizations should register helpers in advance in order to create the legal framework. The advantage of personal registration lies in determining the knowledge and skills of spontaneous helpers with regard to upcoming activities.

Another important aspect of coordinating spontaneous helpers is targeted assignment. Otherwise, there is a risk of too many helpers approaching an assignment location. The oversupply compared to the work available can lead to frustration and the feeling that the descriptions in the appeals (e.g. on social networks) do not correspond to reality. One possible consequence of this is that the willingness of potential helpers to provide support in future situations decreases as a result of their experiences. Public dissemination of these experiences could weaken the system of spontaneous helpers in the long term. One interviewee gave an indication of this assumption by noting that helpers from the neighbouring town of Eschweiler moved on to Stolberg because no organization was apparent to them and, as a result, they were not assigned to take up activities. A shift is therefore to be expected in larger situations. In the example described, the groups in Stolberg benefited from the lack of organization in the neighbouring town, which increased the possibilities for sending manpower. It was not possible to determine from the available data what changes resulted from this action. This would require further research.

The results also showed that the allocation of tasks and activities by spontaneous helpers varied. However, it should be noted that processing was ensured by each procedure. It is not possible to conclusively answer the question of whether a particular procedure resulted in faster processing compared to other procedures. In many cases, the spontaneous helpers were not able to fully document the high number of inquiries and, as a result, orders, stating the times involved. In addition, a lot of assistance was provided directly on call. This is where the advantage lies in the processing of operations by the BOS with the aid of operations control software in control centers or situation centers. The extent to which the recording of activities within the scope of cooperation with the BOS can be ensured by their systems must be checked by the respective responsible body. In any case, however, a fail-safe system must be guaranteed. On the part of the spontaneous responders, however, there are doubts based on experience as to whether the authorities or BOS can provide coordination to this extent.

As the results clearly show, in the initial phase of the relief efforts, uncomplicated activities were carried out, which were limited to the collection, preparation and distribution of food, clearing mud and the acceptance and collection of clothing donations. The spontaneous helpers only gradually took on more specific tasks as time went on, including, for example, helping to set up contact points, beer tent sets and camp beds with the involvement of aid organizations (e.g. DRK and MHD), setting up donation warehouses (e.g. for tools and building materials) and clearing out the

affected properties and areas. During the interviews, it was noted that these activities could be carried out without the helpers having any previous experience. Even for more specific tasks, no extensive instruction was required, as previous knowledge from the private or professional environment meant that they could be implemented without the involvement of the authorities or BOS. When looking at the professional backgrounds of the helpers, it is noticeable that not only purely manual activities were helpful on site, but also the knowledge and skills of graphic designers and office staff led to a contribution in the form of additional work or support services outside the damage area to help cope with the situation.
The different perceptions with regard to the dangers involved in the activities undertaken are also significant. While an increasing understanding of the safe performance of tasks is evident among spontaneous aid groups, the respondents consider observed individual actions (e.g. clean-up work in the riverbed shortly after the incident) to be critical. According to the interviewees, the previous, partly legal, requirements in the context of the COVID-19 pandemic were hardly observed by the helpers when providing assistance. It can therefore be assumed that aid workers considered the flood disaster to be more significant than the pandemic at the time. Protection against possible pollutants in the mud or on the furniture during the clear-out also played a subordinate role for the spontaneous helpers deployed, at least in the initial phase. The BOS should therefore inform the population about possible dangers with regard to the handling of certain substances at an early stage. Whether the aspect of helpers putting themselves in danger is solely due to their high motivation or lack of knowledge can only be assumed and cannot be answered with any certainty on the basis of the available data. As a comparison with the existing literature did not provide any clues, further research is required in this regard.

Conclusion and outlook

On the one hand, the aim was to identify optimization approaches with regard to the involvement and coordination of spontaneous helpers. On the other hand, the study examined which measures are required to promote cooperation between state authorities and spontaneous helpers. Due to the small number of study participants and the isolated approach to the flood disaster in the town of Stolberg, it is not possible to draw any generally applicable conclusions. Nevertheless, this study can generate valuable and meaningful findings.

What criteria do spontaneous helpers use to decide whether, when and where to help?

Spontaneous helpers have a connection to the assistance provided by family members and friends and acquaintances. They also have a local connection to the disaster area. The willingness to help is reinforced by the perception of the representations in social networks, regional and national media as well as reports by helpers and those affected. This also determines the timing of the start of activities. The decision as to where to start work is made via social networks and by observing the gathering of helpers in the damaged area. Central or well-known locations such as the local town hall, church or marketplace often serve as initial points of contact for networking with other spontaneous helpers.

What support do spontaneous helpers expect from state authorities?

Above all, a clear allocation of areas for the formation of collection and contact points or storage locations and the appointment of fixed contact persons on the part of the authorities or BOS are expected. Material support, e.g. in the form of transportation, is also desired.

How can mutual contact be established to coordinate assistance?

Contact with spontaneous helpers must be made at an early stage by the authorities via liaison persons. Social networks can be helpful for initial contact. Furthermore, contact and collection points for spontaneous helpers should be set up and permanent contact persons appointed.

Are social networks such as Facebook and Instagram for bundling and coordinating help the focus of spontaneous helpers or are official coordination centers, e.g. a telephone hotline, desirable?

Social networks are the focus of the coordination of spontaneous helpers. At the same time, a structure must be created locally at an early stage. Contact and collection points can be helpful. Coordination can be supported by technical solutions such as apps, websites and a citizens' hotline.

What factors influence cooperation with state authorities and among spontaneous helpers themselves?

The opportunities for self-realization and free fulfillment of tasks play an essential role for spontaneous helpers in the context of cooperation. In this context, the respect and trust shown by the authorities and BOS, as well as honesty, attentiveness and sensitivity towards spontaneous helpers, are crucial.

What measures and actions are required in the run-up to a disaster in order to promote mutual understanding and coordination?

The task of the authorities and BOS is to build and establish a permanent communication structure. This includes promoting the websites and social networks of the municipalities and districts. App-based solutions should also be considered, taking technical progress into account. In addition, it is important to ensure that contact is maintained with groups of spontaneous helpers that have emerged. Intermediary organizations could take over the monitoring of progress and development in future situations.

In conclusion, it can be stated that the knowledge gained has shown that basic theoretical assumptions were largely confirmed during the flood disaster in Stolberg and that communication played a central role in the success of cooperation between the authorities or BOS and spontaneous helpers. The early integration of spontaneous helpers can lead to faster disaster management. However, it has also become clear that further scientific attention is required and that concepts/guidelines need to be established at grassroots level, i.e. at municipal level.

Literature

Bartz, Michael (2024): Zusammenarbeit zwischen staatlichen Behörden und Spontanhelfenden - Optimierungsansätze zur Koordinierung von Spontanhelfenden am Beispiel der Flutkatastrophe 2021 in Stolberg (Rhld.) in: *Forschung für den Bevölkerungsschutz – Kongressband I*, Bonn: BBK, 2024.

Betke, Hans, Sebastian Lindner, Stefan Sackmann & Sophie Gerstmann (2017): Informationssysteme im Katastrophenmanagement – Entwurf eines Koordinationssystems für ungebundene Helfer in: Maximilian Eibl, Martin Gaedke (Hrsg.): INFORMA-TIK 2017, Lecture Notes in Informatics (LNI), Bonn: Gesellschaft für Informatik, 2017.

Bledau, Lena, Janina Braun, Cordula Dittmer, Michaela Führer, Lars Gerhold, Andrea Jungmann, , Daniel Lorenz, Thomas Kox, Monika C. Muszynska, Jessica Reiter, Jochen Schiller & Martin Voss (2014): Organisationsstudie „Steuerungsmöglichkei-ten für einen zukunfts- und leistungsfähigen Katastrophenschutzdienst in Schleswig-Hol-stein unter den Gesichtspunkten der Ehrenamtlichkeit sowie veränderter gesellschaftlicher und wirtschaftlicher Rahmenbedingungen", Berlin: Freie Universität, 2014.

Drews, Patrick (2019): Konzepte zur Einbindung von ad-hoc-Helfern zur Substitution ausfallender Einsatzkräfte - REBEKA: Abschlussbericht: Bekanntmachung: Zivile Si-cherheit - Erhöhung der Resilienz im Krisen- und Katastrophenfall, Stuttgart: Universität Stuttgart, 2019, doi:10.2314/KXP:1688174710.

Fathi, Ramian, C. Tonn, Y. Schulte, A. Spang, M. Gründler, F. Kletti, Frank Fiedrich, A. Fekete, & S. Martini (2016): Untersuchung der Motivationsfaktoren von Spontanhelfern In: Deutsches Rotes Kreuz, Die Rolle von ungebundenen HelferInnen bei der Bewältigung von Schadensereignissen – Teil 3, Handlungs- und Umsetzungsempfehlungen für den Einsatz ungebundener HelferInnen, Berlin: DRK, 2016.

IM NRW (2022): Katastrophenschutz der Zukunft – Abschlussbericht des vom Minister des Innern berufenen Kompetenzteams Katastrophenschutz, Düsseldorf: IM NRW, 2022.

Kaczmarek, Sabina & Marcel Diederichs (Hrsg.) (2016): Forschungs-projekt ensure, Verbesserte Krisenbewältigung im urbanen Raum durch situationsbezogene Helferkonzepte und Warnsysteme, Abschlussbroschüre, Berlin: Berliner Feuer-wehr, 2016.

Kircher, Frieder (2014): Ungebundene Helfer im Katastrophenschutz in: Brand Schutz, 68(8), Stuttgart: Kohlhammer, S. 593-597.

Martin-Luther-Universität Halle-Wittenberg (Uni Halle, 2020): KUBAS Abschlussbericht zum Teilvorhaben Automatisierte Kommunikationsworkflows zur Einbindung freiwilli-ger Helfer in das Katastrophenmanagement (ASK), Halle: MLU, 2020

MULNV (2021): Zweiter fortgeschriebener Bericht zu Hochwasserereignissen Mitte Juli 2021 (zu Landtags-Vorlage 17/5485), Sitzung AULNV am 25.08.2021, Düsseldorf: MULNV, 2021.

Rusch, Gebhard, Christoph Kotthaus & Sascha Skudelny (2019): KOKOS, Abschlussbericht: Unterstützung der Kooperation mit freiwilligen Helfern in komplexen Einsatzlagen, Siegen: Universität Siegen, 2019.

Schwartz, S.H. & J.A. Howard, (1981): A normative decision-making model of altruism. in: J.P. Rushton; R.M. sorrentino (Hrsg.) *Altruism and helping behaviour*, S. 189-211.

Universität Stuttgart (2018c): Tätigkeitenkatalog für Spontanhelfende, Stuttgart: Universität Stuttgart, 2018.

Winter, Ruth & Julian Brückner (2022): Abschlussbericht WuKAS – MHD,

Köln: Malteser Hilfsdienst e.V., 2022
Zettl, Veronika (2018): Handlungsleitfaden für BOS zur Zusammenarbeit mit Mittlerorganisationen in Schadenlagen, Stuttgart: IAT der Universität Stuttgart, 2018.

Link to presentation

https://thga.sciebo.de/s/R3zJV88vnzhygzP

Demonstration of the dangers of lithium-ion batteries for firefighters

Marvin Janßen, Monika Rode

Institut der Feuerwehr Nordrhein-Westfalen

Key points

I. The demand for stationary energy storage (from LIB home storage to large-scale LIB storage) is currently increasing progressively.

II. Fire services will be confronted more frequently in future with operations involving stationary LIB energy storage systems.

III. The experiential training will prepare firefighters for such operational scenarios.

Abstract

Es ist festzustellen, dass stationäre Energiespeicheranlagen aus Lithium-Ionen-Batterien, d. h. Heim-, Industrie- und Großspeicher, vermehrt installiert werden aufgrund des steigenden Bedarfes nach Energiespeicherung. Für die Feuerwehr bringt diese Entwicklung potenziell neue Herausforderungen mit sich, einige Einsatzgeschehen sind den Medien bereits zu entnehmen.

In dem Projekt „Sicherheit elektrochemischer Energiespeicher in Second-Life-Anwendungen" mit dem Akronym SEE-2L standen stationäre Lithium-Ionen-Energiespeicher in Second-Life-Anwendungen („First-Life" als Traktionsbatterien in Elektrofahrzeugen) im Fokus (Bundesanstalt für Materialforschung und -prüfung 2021). Ergänzend setzten sich die Vereinigung zur Förderung des Deutschen Brandschutzes e. V. (vfdb) und das Institut der Feuerwehr Nordrhein-Westfalen (IdF NRW) mit einem modularen Schulungskonzept für Einsatzkräfte für Lithium-Ionen-Technologie auseinander – vom Consumer-Bereich über Elektromobilität bis zu Großspeicheranlagen im MWh-Bereich. Den Einsatzkräften eine erlebbare Ausbildung zu dieser Thematik zu ermöglichen war ein besonderes Anliegen.

Introduction

It can be seen that stationary energy storage systems using lithium-ion batteries, i.e. home, industrial and large-scale storage systems, are increasingly being installed due to the growing demand for energy storage. This development potentially poses new challenges for the fire department, and some incidents have already been reported in the media.

In the project "Safety of electrochemical energy storage in second-life applications" with the acronym SEE-2L, the focus was on stationary lithium-ion energy storage in second-life applications ("first-life" as traction batteries in electric vehicles) (Federal Institute for Materials Research and Testing 2021). In addition, the Association for the Promotion of German Fire Protection (vfdb) and the Institute of Fire Brigade of Nordrhein-Westfalen (IdF NRW) are working on a modular training concept for emergency services for lithium-ion technology - from the consumer sector to electromobility and large storage systems in the MWh range. Providing the emergency services with hands-on training on this topic was a particular concern.

The Institute of Fire Brigade of Nordrhein-Westfallen in research

The IdF NRW is the central training and further education center with competence centers for the improvement and further development of fire protection, assistance and disaster control in the state of North Rhine-Westphalia. Management and specialized training for professional and volunteer firefighters from both public and private fire brigades takes place here all year round. In addition, operational-tactical command teams and administrative-organizational crisis teams are trained and further educated. With a staff of around 220 employees, the IdF NRW is the largest German fire service training center. The institute is involved in national research projects as an associated partner, subcontractor or increasingly as a full partner. At EU level, it has been or is involved in the DRIVER+ and STRATEGY projects, among others.

The Research division is part of the K2 "Crisis Management and Research" department. In addition to active participation in research projects and the associated recruitment of qualified scientific staff, student theses are also regularly carried out and supervised here.

The dangers of stationary LIB storage systems for Firefighter Brigade

Distribution of stationary LIB storage systems

As already mentioned, the SEE-2L project focused on stationary LIB storage systems. In principle, stationary energy storage systems can be divided into three classes (Figgener et al. 2023):

- **Home storage**[8]: approx. 55 % of home storage systems in Germany are in the 5 to 10 kWh range and over 30% in the 10 to 15 kWh range
- **Industrial storage**: approx. 85 % of industrial storage systems in Germany are in the 30 to 100 kWh range.
- **Large storage systems**: over 75 % of large storage systems in Germany are in the 1 to 10 MWh range

In the work by Figgener et al., the absolute installations of stationary energy storage systems were broken down according to their classes. This was filtered as follows: home storage systems (HSS) ≤ 30 kWh, industrial storage systems (ISS) 30 kWh to 1000 kWh, large-scale storage systems (LSS) ≥ 1000 kWh.

[8] By comparison, the average battery capacity of available electric vehicle models is 68.6 kWh (EV Database 2023).

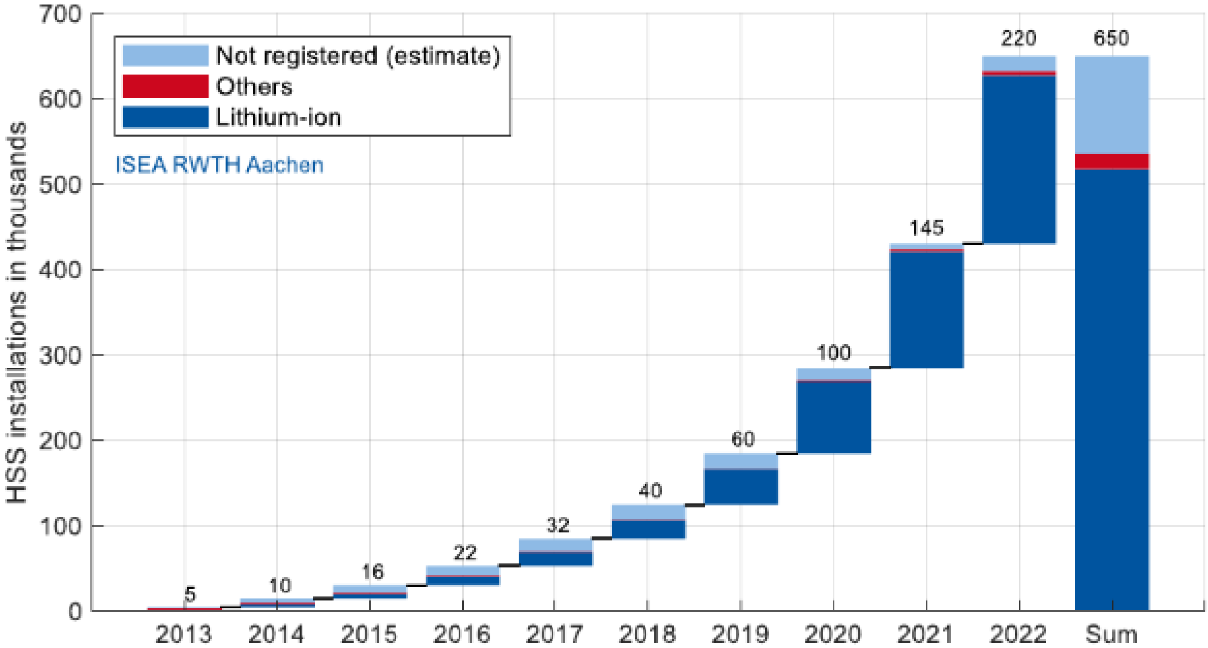


Figure 1: (Estimated) The number of installed home storage systems in Germany (Figgener et al. 2023)

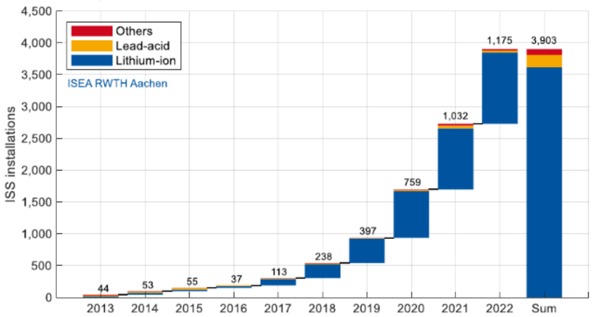


Figure 1: (Estimated) The number of installed industrial storage systems in Germany (Figgener et al. 2023)

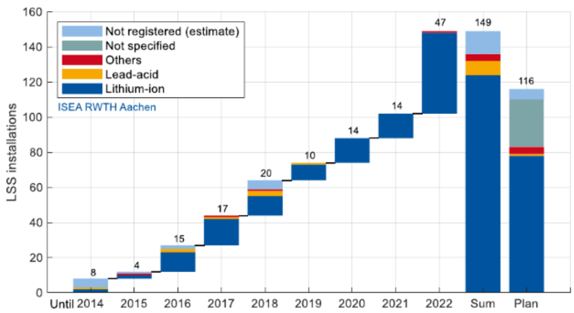


Figure 2: (Estimated) The number of installed large-scale storage systems in Germany (Figgener et al. 2023)

Figures 1 and 2 clearly show the progressive increase in installations of corresponding battery storage systems. The expansion of large-scale storage systems took a leap in 2022 (see Figure 3). It is expected that this trend in the expansion of storage systems will continue in the coming years due to the demand created by the current (global) political situation.

If the home storage systems installed in Germany up to and including 2022 are set in relation to the number of residential buildings (as of 2021 including residential homes: 19,375,911) (Federal Statistical Office 2021), it is estimated that 3.4 % of residential buildings are currently equipped with a stationary battery storage system. The only assumption in this analysis is that each installed storage system supplies one residential building. However, it must be taken into account that this is only a snapshot. Current developments and political demands suggest that the installation of home storage systems will increase significantly over the coming years and that industrial and large-scale storage systems will also be further expanded.

The dangers and challenges for Firefighters due to LIB

The fire service has been dealing with the potential dangers of LIB for some time now due to the increasing number of electric vehicles on the roads. It is also known that the cause of (building) fires has been increasingly attributable to LIB for several years (Institute for Loss Prevention and Claims Research 2023, New York Post 2023), which is primarily due to the increasing spread of this technology in everyday life, especially in the consumer sector.

In the area of stationary LIB storage, however, the fire service is confronted with much larger batteries and therefore a higher hazard potential. In order to increase the safety of the emergency services during an operation with damaged stationary LIB storage systems, it is important that they are able to correctly assess the potential hazards to be expected.

Most firefighters are already familiar with the thermal runaway in LIBs. This is demonstrated very impressively on a BAM YouTube channel; three Videos[9] from the tests in the SEE-2L project show the extreme fire behavior of individual battery modules (Federal Institute for Materials Research and Testing 2023).

Furthermore, the majority of emergency services are also aware of the formation of hydrofluoric acid in connection with continuous LIBs. But does this actually pose the greatest or even the only danger to the personnel deployed?

The formation of hydrofluoric acid is generally to be expected during the thermal runaway of LIBs, as the fluorine-containing conductive salt lithium hexafluorophosphate (LiPF6) is used in most cells, which reacts with water to form hydrogen fluoride (HF) or its aqueous solution hydrofluoric acid (Korthauer 2013). To assess this hazard, however, the "Acute Exposure Guideline Levels" (AEGL) should be considered, as Tschirschwitz et al. (2023) did in their experiments. Of course, this risk should not be neglected, but it must always be considered in relation to other factors.

It is generally to be expected that LIB fires will not only produce hydrofluoric acid, but also various other toxic and flammable gases. Examples of toxic gases produced are hydrogen chloride (HCl), monophosphane (PH_3), nitrogen monoxide (NO) and, above all, large quantities of carbon monoxide (CO). In addition to large quantities of carbon monoxide (CO) and hydrogen (H_2), flammable gases also include various alkanes and alkenes such as methane (CH_4), ethane (C_2H_6), ethylene (C_2H_4) and electrolyte components such as dimethyl carbonate ($C_3H_6O_3$), ethyl methyl carbonate ($C_4H_8O_3$) (Korthauer 2013, Rappsilber et al. 2023, Tschirschiwtz et al. 2023). The quantity and composition of the resulting gas mixtures always depend on several factors such as the cell chemistry (active material of the electrodes, electrolyte), design (cylindrical, prismatic, pouch), capacity or size of the storage unit, state of charge and ageing condition. Increasing importance in the risk assessment is now attributed to the heavy metals released, which are released as aerosols into the fire smoke through the combustion of the electrode materials (Federal Ministry for Climate Protection 2021) or are deposited as dust on the firefighter's clothing and the scene of the incident. However, emergency crews should be protected from such hazards by

[9] Direct link to BAM Youtube channel: https://www.youtube.com/@bamresearch/videos.

standard personal protective equipment for indoor firefighting and thorough emergency site hygiene (DGUV 2023). However, the further research in this area would be desirable.

The risk of explosion is a major risk when using stationary LIB storage tanks. Particularly in the case of home storage tanks, which are often installed in basements, there are insufficient ventilation options. If a home storage system fails, i.e. thermal runaway and propagation to several/all cells, an explosive atmosphere could form in the room volume of the installation site. Even an intact battery storage system that is thermally overstressed by an external fire poses the risk of extreme fire behavior, i.e. thermal runaway. If an explosive gas mixture has not ignited by the time the first emergency services arrive due to a lack of oxygen or an ignition source, this could pose an extreme risk to the emergency services as soon as they attempt to gain access to the source of the fire. Such an incident at a large storage facility with four seriously injured emergency personnel confirms this danger. In this incident, an explosion occurred at a large storage facility in the USA in 2019. Prior to the explosion, the emergency services were able to detect low-lying white clouds of gas and smoke with an acrid odour in the area where the large storage facility was located (Institute of Fire Safety Research 2020).

The "extinguishing" of LIB fires poses a challenge in that the propagation of thermal runaway to surrounding cells in a storage system can hardly be prevented in the long term. In most cases, it is not possible to introduce the currently most suitable extinguishing agent, water, possibly with the addition of a wetting agent, into the densely packed and sealed battery storage system in order to effectively extract sufficient energy directly from the affected cells through the cooling effect of the water. However, even then it must be assumed that neighboring cells of a cell that has already undergone thermal runaway could run away after the continuous cooling measures have been completed, as chemical decomposition processes have already been initiated in these neighboring cells by exceeding a critical temperature threshold (exothermic reaction), but these have only been slowed down by the cooling measures. Last but not least, attention must also be paid to extinguishing water contamination and thus extinguishing water retention. The extinguishing water can become highly alkaline during prolonged direct contact with LIB that has passed through, e.g. by being immersed in a water tank (Institute for Safety Technology/Marine Safety 2021).

Selection of real events

Of course, not every installed stationary battery storage system escalates into a damage incident or an operation for the fire brigade. An internet search on the subject of "fire + lithium-ion battery" reveals that fire brigades around the world have so far had to deal with relatively few incidents involving stationary battery storage systems. What is striking is that these incidents have often attracted a great deal of public and media interest. However, conversations with emergency services indicate that there is often uncertainty regarding the tactical approach and risk assessment.

Selected real-life incidents are listed below to emphasize the challenges of operations involving damaged LIBs and their potential severity. In particular, the aforementioned incident in the USA in 2019, in which four emergency personnel were seriously injured by an explosion in a large storage tank, clearly shows the serious consequences that can result from "wrong" tactical decisions in these scenarios.

Figure 4: Explosion in large storage facility (Fire Safety Research Institute 2020)

19.04.2019, USA, Suprise (Arizona), Large storage facility, Explosion:

Explosion in a 2.16 MWh LIB large storage tank (single, free-standing "building" or container) with four seriously injured firefighters from the hazardous materials unit (HAZMAT) after they opened the door to the storage building.

Figure 5: Fire at a large storage facility (KFV Märksisch-Oderland e.V. 2021)

18.07.2021, Germany, Neuhardenburg (Brandenburg), Large storage facility, fire:

Fire at a 5 MW LIB large storage facility; 11 firefighters were taken to hospital for observation as a precautionary measure due to suspected contamination with hydrofluoric acid.

Figure 6: Explosion of a home storage tank lifts the roof truss (FF Bodnegg 2022)

03.03.2022, Germany, Bodnegg (Baden-Würtemberg), Home storage, Explosion:

Explosion with subsequent smouldering fire in the basement of an apartment building, triggered by a PV home storage system located there; the resulting pressure wave pushed several windows and doors outwards and lifted the roof truss.

Figure 7: Explosion of a home storage tank leads to partial collapse (Vogelsberger Zeitung 2023)

06.10.2023, Germany, Wernges (Hessen), Home storage, Explosion:

Explosion of a 30 kWh home storage unit with LFP cell chemistry in the basement of a residential building; the explosion leads to a partial collapse of the building; one person is injured.

Assessment of stationary LIB storage systems from a fire service perspective

Although stationary LIB storage systems are currently distributed throughout Germany, the fire service does not (yet) have to expect to be frequently confronted with the dangers of stationary LI battery storage systems due to the distribution situation of these storage systems illustrated in Chapter 3.1.

While LIBs have been ubiquitous in the consumer sector for several years and can probably be found in every household (smartphones, laptops, battery-powered tools, etc.), this is not yet the case for stationary applications. It is only in the last two to three years that stationary applications of LI technology have become significantly more important (Figgener et al. 2023). It is currently becoming apparent that this trend curve will continue until a saturation point is reached - it is not yet possible to estimate how high or low this point will be. However, the current trend is more in favor of a high saturation point, meaning that in future, for example, every third or even every second residential building could have such a storage system.

The recently amended M-EltBauVO (last amended in 2022) now facilitates the installation of battery storage systems in residential buildings, among other things. Battery storage systems up to 20 kWh have been explicitly excluded from the scope of this model ordinance, which means that no special fire protection regulations apply to the installation of such home storage systems. This change will accelerate the spread of home storage systems, provided it is implemented accordingly in state law. Furthermore, laymen's DIY instructions for home storage units are increasingly available on the Internet. It is also to be expected that greater technological maturity of the LIB will reduce market prices, making stationary energy storage systems more cost-effective and therefore more attractive in the coming years. Second-life applications for traction batteries already in use are also very likely to accelerate their spread. The federal state of Baden-Württemberg, for example, now requires the installation of PV systems in new buildings and fundamental roof renovations, which will also lead to many homeowners installing additional battery storage systems in the future.

However, precisely because the number of real-life incidents is still very low and the fire services therefore lack a basis of experience, it is all the more important to address this topic efficiently in fire service training. This is because the potential dangers posed by LIBs should not be underestimated, especially in the dimensions and scenarios of stationary systems, as the few real events in Chapter 3.3 illustrate. A malfunctioning home storage system in a basement with inadequate ventilation options can lead to the formation of an explosive atmosphere.

It remains to be seen how often fire brigades in Germany will actually be confronted with such emergency situations in the future. So far, there are no reliable statistics on this. However, incidents such as those described in Figure 4 must be avoided through suitable training content, even if the number of stationary LIB storage systems currently installed is still relatively low and the probability of damage events occurring is therefore automatically low.

The extent to which, for example, the progressive ageing of the installed LIBs increases the risk of failure and thus the probability of occurrence of corresponding damage events cannot be conclusively assessed at this time. However, such a relationship could mean that the probability of damage events occurring not only correlates linearly with the spread of storage systems, but also increases more strongly in the future due to a higher average age of all installed battery storage systems.

The popular fire brigade phrase "getting ahead of the situation" could be used here: Stationary LIB storage systems on this scale are still new from a fire service perspective and therefore represent a new challenge across the board; although the fact that the fire service is already involved with LIB technology at the electromobility level is an advantage here. The first recommendations for the fire service's handling of stationary battery storage systems already exist (German Association for Energy Storage Systems 2021). The next step is to ensure that the knowledge gained is transferred to the emergency services in a sustainable manner so that it is available to them in the event of an emergency. This is where the IdF NRW is taking the initiative by participating in the SEE-2L research project with the aim of training emergency services with suitable training concepts.

The role of the demonstrator in the training concept

In order to ensure a sustainable transfer of the research findings to the user level, the SEE-2L project envisaged the development and construction of a decentralized test stand as a part of a training concept. This will allow the emergency services to be trained to "experience training", which, in conjunction with the training concept, will help to consolidate the knowledge learnt. Thanks to its mobile design, the trainer can also be set up at other locations.

The mobile demonstrator has the rough dimensions of 1.5 m x 1.2 m x 1.5 m (LxWxH) and is equipped with multi-gas measurement technology, thermocouples, thermal imaging and cameras, among other things.

A design draft for the demonstrator was created as part of a master's thesis at IdF NRW (see Figure 8). After several preliminary tests, the demonstrator has now been officially presented to the public in a media-effective manner (vfdb 2023, see Figure 11) and is currently being fine-tuned so that it can be profitably integrated into tangible training for firefighters in the future. The test stand is not designed exclusively for LIB or a specific cell chemistry or cell design, but could also be used for other test projects together with the installed measurement technology. One example is solid-state batteries, which could become increasingly relevant in the future.

Figure 9 and Figure 10 show examples of the impressions that the emergency services can gather during the demonstration tests. The cathode material of the pouch cells used is nickel-manganese-cobalt (NMC). Figure 9 shows a snapshot of a 6000 mAh pouch cell during the thermal runaway - the cell gradually reacts thermally starting at the pole flags. This allows the emergency services to gain a basic understanding of the behavior of individual LIB cells during thermal runaway. Supported by several built-in thermocouples with digital indicators, the emergency services can get an idea of the resulting temperatures on the one hand, and on the other hand it can be demonstrated that the LIB will continue to heat up exothermically on its own once a critical temperature threshold has been exceeded, despite the heating plate being switched off, until a severe thermal runaway occurs. Translated into a real operational scenario, emergency services can use this knowledge to better categorize the condition of a battery storage unit: By monitoring the temperature at set intervals using a thermal imaging camera, it is possible to make an initial assessment of whether a storage unit is heating up on its own and is therefore in a critical condition. A temperature log can be kept for monitoring purposes. For example, the tactic of cooling the storage tank from cover could be used - however, alternative measures are also discussed as part of the training concept.

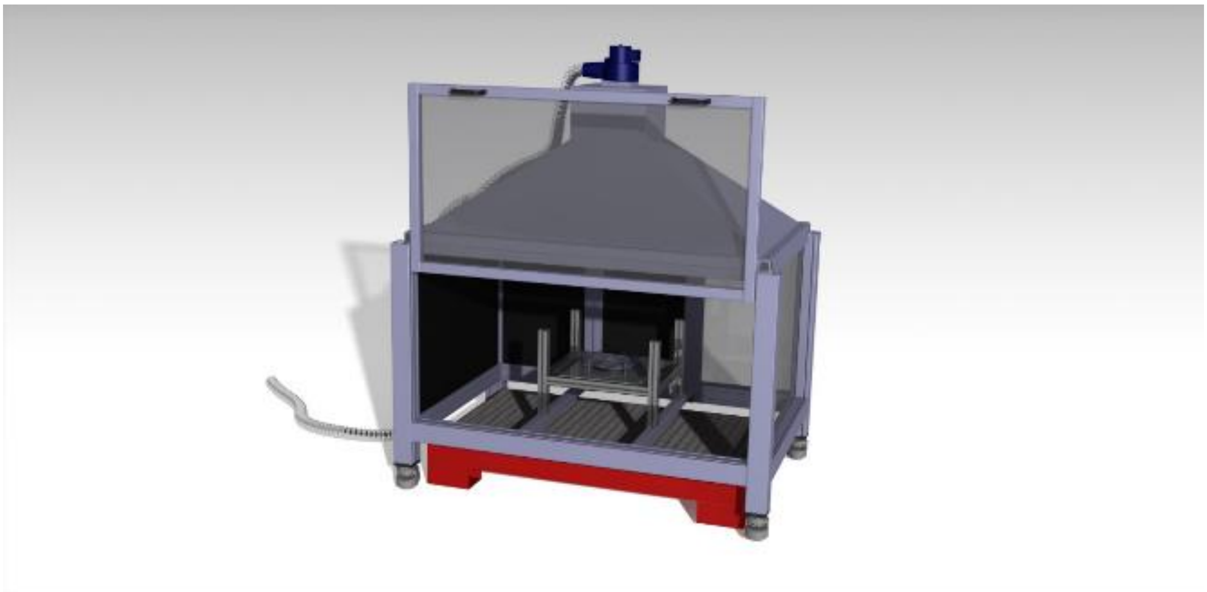


Figure 8: Final CAD-Model Demonstrator (Janßen 2022)

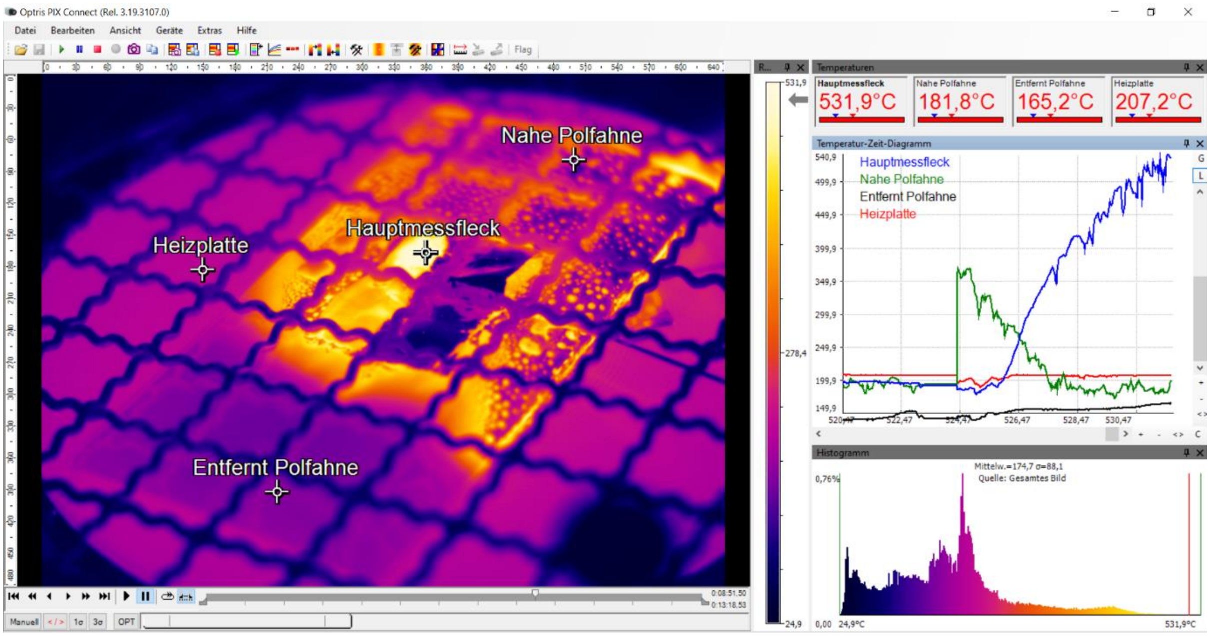


Figure 9: Thermal image of a 6,000 mAh pouch cell during the thermal runaway on the heating plate in the demonstrator (Janßen & Saupe 2023)

Figure 10 shows a typical flame pattern for continuous LIBs, so-called "jet flames". During thermal runaway, decomposition products are formed in the cell, causing the internal cell pressure to rise until the cell ruptures at its mechanically weakest point and ejects the gases under increased pressure ("venting"). If these expelled flammable gases ignite, depending on the energy content of the cell, jet flames can be expected that can reach several meters. The capacity of the 10,000 mAh cell used (37 Wh) is roughly 2.5 times that of a smartphone battery. What is already impressive with such a small LIB can now be scaled up to an average 10,000 Wh home storage unit, for example. An explosion of the resulting gases cannot yet be influenced and reproducibly demonstrated in the demonstrator, although it did occur during one of the preliminary tests. This shows that the behavior of LIB under real conditions cannot always be accurately predicted. The demonstrator was designed to protect the participants in the event of an explosion by being sealed except for the floor assembly for pressure relief. In a real-life scenario, in addition to the risk of a gas explosion, accelerated metal splinters from the battery enclosure are also to be expected. During a BAM overload test in the SEE-2L project, a 17 cm long metal part was ejected 33.2 m from the test stand (Tschirschiwtz et al. 2023).

Furthermore, some of the gases produced can be detected using the "standard fire brigade" gas measurement technology installed. A multi-gas detector is equipped with Ex, CO, CO_2, O_2 and H_2 sensors for this purpose. A single gas detector with an HF sensor is also used. This allows the emergency services to see which gases can be measured immediately before the thermal runaway as an indication of this or which ultimately lead to an explosive gas mixture.

Figure 10: Jet flame during the thermal runaway of a 10,000 mAh pouch cell in the demonstrator (Janßen & Saupe 2023)

Figure 11: Opening event demonstrator (IdF NRW 2023)

The training concept developed in cooperation with the vfdb currently consists of eight different modules, of which the practical experiment with the demonstrator is just one. The modules cover a range of topics, from the necessary theoretical foundations surrounding LIBs (lithium-ion batteries), including where they are expected to be found and how to recognize them, to recommendations and guidance on tactical deployment approaches.

Within the module on tactical deployment approaches, various deployment scenarios are considered as theoretical exercises to discuss potential action strategies. Here, the knowledge gained from the previous modules regarding LIBs—such as where they are installed, how to recognize them, their potential hazards, etc.—is applied by the emergency responders. For example, one of these exercises sets the scenario where "there is unclear smoke development in the basement of a single-family house. Upon investigation, a photovoltaic system is observed on the roof of the building, and relatively dense but bright smoke is seen in the basement windows; further information is not available." During the demonstration experiment, emergency responders were able to experience firsthand the behavior of a LIB in case of failure using their own senses, and they know, among other things, what venting gases look like and how they can be measured if necessary. Through the overall training concept, emergency responders are sensitized to the possibility of encountering a home storage system in such a deployment scenario and should adjust their deployment tactics accordingly based on the recognized potential hazards, such as the risk of explosion.

Discussion

The mobile demonstrator and the teaching materials provide emergency responders with an "experiential" education on potential dangers posed by lithium-ion batteries (LIBs) in relevant deployment scenarios. The training concept for handling LIB technology in combination with the demonstrator prepares emergency responders for future deployments.

As the number of installed storage systems increases and their aging progresses, firefighting operations involving stationary LIB storage units are expected to rise. However, it is also anticipated that the safety of installed storage units will improve, thus reducing the probability of individual battery storage unit failures. Nevertheless, this circumstance could present new challenges to the fire service. For instance, if propagation at the cell or module level, as in the case of home storage, can effectively be prevented until the arrival of emergency responders, the failure may initially involve only one or a few cells. However, in such cases, it must be assumed that neighboring cells have been critically affected by the thermal runaway of a single cell, causing them to temporarily exceed their intended operating conditions (temperature, pressure, etc.). Consequently, the entire storage unit is in an undefined state and must be considered critically defective. At this stage, it cannot be ruled out that the remaining energy stored in the unit may be released suddenly due to a thermal runaway. The danger is thus not entirely averted. To safely release the deployment site, the storage unit would need to be dismantled and removed from the building. However, this is currently challenging due to the complex dismantling process and the necessary separation from other electrical system components, a task that must be performed by appropriately qualified personnel. During such operations, the critical condition of a storage unit poses a high safety risk to emergency responders/specialized personnel.

It is crucial to involve the fire service as end-users in research projects right from the outset to identify and address their needs. Challenges such as those mentioned above could thus be identified early, and solutions could be formulated.

Literature

AGBF – Arbeitsgemeinschaft der Leiter der Berufsfeuerwehren Bund & DFV – Deutscher Feuerwehrverband e. V. (2021): Brandbekämpfung von Kraftfahrzeugen mit elektrischen Antrieben, https://www.agbf.de/downloads-fachausschuss-vorbeugender-brand-und-gefahrenschutz/category/28-fa-vbg-oeffentlich-empfehlungen?download=356:2021-01-fachempfehlung-elektrofahrzeuge [23.05.2024].

Balsamini, Dean (2023): E-Bike Battery Fires This Year Have Killed More in NYC Than in 2022: FDNY, in: *New York Post*, https://nypost.com/2023/06/03/e-bike-battery-fires-this-year-have-killed-more-in-nyc-than-in-2022-fdny/ [23.05.2024].

Bundesanstalt für Materialforschung und –prüfung (2023): *#2ndlife Energiespeicher*, https://www.youtube.com/@bamresearch/videos [07.02.2024].

Bundesanstalt für Materialforschung und –prüfung (2021): SEE-2L – Stationäre elektrische Energiespeicher – Second Life Anwendungen, https://www.bam.de/Content/DE/Projekte/SEE-2L/see-2l.html [07.02.2024].

Sturm, Peter, Patrik Fößleitner, Daniel Fruhwirt, Simon Heindl, Bernhard Kohl, Oliver Heger, Robert Galler, Robert Wenighofer, Stefan Krausbar (2021): BRAFA. Brandauswirkungen von Fahrzeugen mit alternativen Antriebssystemen, https://www.itna.tugraz.at/assets/files/areas/vuu/BRAFA_Ergebnisbericht_v1.0.pdfBundesverband Energiespeicher Systeme e. V. (2021): Vorbeugender und abwehrender Brandschutz bei Lithium-Ionen Großspeichersystemen, https://www.agbf.de/downloads-fachausschuss-vorbeugender-brand-und-gefahrenschutz/category/28-fa-vbg-oeffentlich-empfehlungen?download=358:2021-02-brandschutz-bei-li-ionen-grossspeichersystemen-anhang-01-bves [23.05.2024].

Destatis – Statistisches Bundesamt (2021): Bestand und Bauabgang von Wohnungen und Wohngebäuden, https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Wohnen/Publikationen/Downloads-Wohnen/fortschreibung-wohnungsbestand-pdf-5312301.pdf?__blob=publicationFile [07.02.2024].

DGUV – Deutsche Gesetzliche Unfallversicherung e.V. (2023): Hinweise für die Brandbekämpfung von Lithium-Ionen-Batterien bei Fahrzeugbränden, https://publikationen.dguv.de/widgets/pdf/download/article/3907 [23.05.2024].

Electric Vehicle Database (o.J.): Nutzbare Batteriekapazität von Elektroautos, https://ev-database.org/de/cheatsheet/useable-battery-capacity-electric-car [07.02.2024].

Figgener, Jan, Christopher Hecht, Jakob Bors, Kai Gerd Spreuer, Kai-Philipp Kairies, Peter Stenzen & Dirk Uwe Sauer (2023): The Development of Battery Storage Systems in Germany: A Market Review (Status 2023), in: *De.arXiv.org (2023-03-23)*, https://arxiv.org/pdf/2203.06762 [23.05.2024].

Freiwillige Feuerwehr Bodnegg (2022): Explosion in Mehrfamilienhaus, http://www.feuerwehr.de/einsatz/berichte/einsatz.php?n=63124 [07.02.2024].

Institut der Feuerwehr Nordrhein-Westfalen (2023): Eröffnung des Demonstrators (interne Dokumentation). Münster.

Institut für Schadenverhütung und Schadenforschung (2023): Die häufigsten Brandursachen, https://www.ifs-ev.org/die-haeufigsten-brandursachen/m [07.02.2024].

Institut für Sicherheitstechnik/Schiffssicherheit e.V. (2021): Forschungsprojekt ALBERO: Transport alternativ betriebener Fahrzeuge auf RoRo-Fährschiffen. Rostock-Warnemünde.

Janßen, Marvin (2022): Entwicklung eines Konzeptes für einen mobilen Demonstrator zur Durchführung von Brand- und Löschversuchen an elektrochemischen Speichern in Second-Life-Anwendungen (Masterthesis). Wilhelmshaven.

Janßen, Marvin & Saupe, Alexander (2023): Vorversuchsreihe am Demonstrator (interne Dokumentation). Münster.

Korthauer, Reiner (Hrsg.) (2013): *Handbuch Lithium-Ionen-Batterien*, Berlin: Springer Vieweg.

Kreisfeuerwehrverband Märkisch-Oderland e.V. (2021): Brand in einer Batteriespeicheranlage in Neuhardenburg, https://kfv-mol.de/Wordpress/Artikel/brand-einer-batteriespeicheranlage-in-neuhardenberg/ [07.02.2024].

Technische Hochschule Georg Agricola

McKinnon, Mark, Sean DeCrane & Steve Kerber (2020): Four Firefighters Injured in Lithium-Ion Battery Energy Storage System Explosion – Arizona, Columbia: UL Firefighter Safety Research Institute, https://dx.doi.org/10.54206/102376/TEHS4612 [23.05.2024].

Rappsilber, Tim, Nawar Yusfi, Simone Krüger, Sarah-Katharina Hahn, Tim-Patrick Fellinger, Jonas Krug von Nidda & Rico Tschirschwitz (2023): Meta-Analysis of Heat Release and Smoke Gas Emission During Thermal Runaway of Lithium-Ion Batteries , in: *Journal of Energy Storage* 60, 1-15, https://doi.org/10.1016/j.est.2022.106579 [23.05.2024].

Tschirschwitz, Rico, Christopher Bernardy, Patrick Wagner, Tim Rappsilber, Christian Liebner, Sarah-Katharina Hahn & Ulrich Krause (2023): Harmful Effects of Lithium-Ion Battery Thermal Runaway: Scale-up Tests From Cell to Second-Life Modules , in: *Royal Society of Chemistry* 13, 20761-20779, 10.1039/d3ra02881j [23.05.2024].

U.S. Environmental Protection Agency (2018): Compiled AEGL Values, https://www.epa.gov/sites/default/files/2018-08/documents/compiled_aegls_update_27jul2018.pdf [07.02.2024].

Vereinigung zur Förderung des Deutschen Brandschutzes e. V. (vfdb) (2023): Pressemeldungen zum Projekt SEE-2L, https://www.vfdb.de/forschung/laufende-projekte/see-2l/pressemeldungen [07.02.2024].

vfdb – Vereinigung zur Förderung des Deutschen Brandschutzes e. V. (2017): Unfallhilfe und Bergen bei Fahrzeugen mit Hochvolt-Systemen, Merkblatt 06/04, https://www.vfdb.de/media/doc/merkblaetter/MB_06_04_2017.pdf [23.05.2024].

Vogelsberger Zeitung (2023): Explosion in Wohnhaus – Einsturzgefahr, https://www.vogelsberger-zeitung.de/2023/10/06/explosion-in-wohnhaus-einsturzgefahr/ [07.02.2024].

Link to Presentation

https://thga.sciebo.de/s/lfoZqWUU2B8X2qV

Integrated hazard prevention planning - focus on the population

Noah Herschbach

antwortING Consulting Engineers PartGmbB

Abstract

The evaluations and lessons learned from the major crises of the last three years have shown that, in addition to adjustments in crisis management and operational hazard prevention, the focus must also be on involving the population, raising their awareness and enabling them to help themselves. As part of integrated hazard prevention planning at municipal level, a participation process can be a suitable means of involving the population in the planning process. This article shows how such a process can be methodically structured and how the various stakeholder groups can be involved. To this end, the experiences and findings from workshops held in North Rhine-Westphalian cities after the 2021 floods were used. The aim was to process the experiences of the population, collect challenges and positive aspects and examine the transferability to other scenarios. The evaluation illustrates the importance of involving the population in municipal hazard prevention planning. The active participation of the population leads to increased risk awareness and thus strengthens the resilience of the respective municipality. In addition, strengthening local networks and improving communication can lead to more effective behavior in crisis situations. Measures such as the establishment of disaster control lighthouses or risk communication concepts are presented as suitable measures to meet the identified challenges.

Initial situation and relevance

In view of the crisis events of recent years, the previous dynamics between the population and state institutions in crisis situations must be reconsidered. The evaluations and lessons learned from the major crises of the last three years have shown that, in addition to adjustments in crisis management and operational emergency response, the focus must be on involving the population, raising their awareness and their ability to help themselves (BBK, 2022a). Understanding the population not as mere recipients of emergency response services, but rather as an active part of emergency response is an approach that can also be derived from the central frameworks for dealing with crisis events. For example, the Sendai Framework and its German implementation strategy see the population as a central pillar of disaster risk reduction and resilience (BMI, 2022; UNISDR, 2015).

The German Federal Government's National Security Strategy, which was only published in June 2023, also defines society as an active part of the interaction with state actors (see Federal Foreign Office, 2023). The population plays a decisive role in crisis management (see Schopp et al., 2023; B˘alteanu and Costache, 2009). Whether in the observance of hygiene measures, commitment to energy-saving measures or active neighborhood assistance in the event of flooding. The personal responsibility and individual emergency preparedness of the population are major capacities for crisis management, even if they have only received marginal attention to date.

A look at three major crisis events in recent years makes it clear that in the crisis management phase, the success of measures depends to a large extent on the behavior of the population and can be influenced by it (cf. Schopp et al., 2023).

Corona pandemic and hygiene measures The fight against the corona pandemic underlines the central role of the population in crisis management. Hygiene measures
such as wearing face masks, hand disinfection and social distancing were among the key measures. However, implementing these measures required a high degree of personal responsibility and discipline, which underlines the importance of self-help skills and crisis communication.

Energy shortages and energy-saving measures The energy crisis has also made it clear that the population can have a significant influence on overcoming the crisis. The population can make a contribution through the conscious use of energy and a commitment to energy-saving measures.

Floods and neighborly help Flood events make it clear how important solidarity and mutual help within the population are in times of crisis. This shows that individual emergency preparedness is not only important at an individual level, but also at a collective level. The active participation of the population in evacuations, property protection or clean-up work can make a significant contribution to minimizing the effects of extreme water events and returning to normality more quickly.

In this context, it is important to clarify that the collective term "population" does not refer to a homogeneous group, but that a wide variety of individuals with different interests, abilities and needs are part of the population (cf. Schopp et al., 2023). This illustration shows that it makes sense to involve the population in planning and preparing for crisis events and to ensure that planning supports resilience in accordance with the capacities for strengthening resilience (cf. DKKV, 2023; Gerhold and Schuchardt, 2021). The realization that it is necessary to involve the population more in all phases of risk and crisis management leads to the question of how planning at municipal level can involve the population. The focus here should be on
This article discusses the question of how municipalities can leverage the potential of population participation in hazard prevention planning and draw conclusions and measures from past situations. This article uses an implementation example to discuss the question of how the population can be involved in municipal hazard prevention planning and what solutions can be derived from the results. Particularly with regard to how a municipality can support the population's self-help.

Integrated hazard prevention planning

Hazard prevention planning at municipal level is a process that can also involve the administration and the population in addition to planning the requirements of the fire and rescue services. The responsibilities within the administration lie in crisis management, the creation of appropriate framework conditions and the preparation of information. As part of emergency response planning, the population can be involved in all phases of municipal risk and crisis management - from prevention to preparation and management to follow-up. Despite the established requirements planning in the area of operational emergency response at municipal level, which ensures that an

emergency response structure is in place that corresponds to local conditions, there is a lack of concepts for involving the population in municipal risk and crisis management.
Questions about the necessary interfaces, preparations and opportunities for participation often remain unanswered. The population plays a central role in coping with crises, especially in unusual and prolonged situations. This was impressively demonstrated by the flood disaster in 2021, when many of those affected were forced to help themselves or others through neighborhood assistance.
Against this backdrop, the question arises as to how the population can be effectively involved in municipal risk and crisis management and what measures need to be taken as part of the development of a holistic resilience concept. Taking into account the potential that lies in the targeted participation of the population. With a view to the municipalities as a state structure and central responsibility for hazard prevention at local level and as a direct point of contact for the population in the event of a crisis, planning can be carried out at municipal level. In the municipal system, regular requirements planning with the fire department, rescue service and civil protection on the operational side is considered, as is the local administration as the body responsible for municipal risk and crisis management. The area of active participation of the population is often a blind spot in municipal hazard prevention planning (Murphy, 2007). Integrated planning primarily involves the interfaces between the planning areas and the consideration of municipal hazard prevention from different perspectives. Here, integrated planning at a systemic level can also be understood as the "planning inclusion" of different perspectives (cf. Müller, 2022). Involving the population can be one way of including them in hazard prevention planning (cf. B˘alteanu and Costache, 2009).

Methodical approach

The data basis for the results presented below is formed by workshops that were held as part of the review of the 2021 floods in cities belonging to districts in North Rhine-Westphalia. The aim of the process was to take the experiences from the 2021 flood and examine how and whether they can be transferred to other scenarios and what measures can be taken to learn from the experiences for future situations and thus strengthen the resilience of the overall municipal system to crises.

The approach includes the understanding that the components of municipal hazard prevention must be dovetailed with each other and options for action must be processed and considered from different perspectives. With this focus, a participation process was designed that involves the population as well as representatives of operational hazard prevention, the administration and operators of critical infrastructure. Figure 1 shows an example of the process, which can be described in four phases.

Involving the population
The aim of the first step of the process is to focus the discussion on the collective experiences in a workshop format with the participation of citizens. A central element of this first process step is the collection of challenges that occurred during the flood disaster as well as positive aspects and experiences that were made despite the difficult circumstances in coping with it. These approaches should help to identify gaps in the preparation and collect aspects that supported self-help. In addition, the transferability of the experience gained to other scenarios was discussed.

The aim is to be better prepared for similar events in the future and to be able to take proactive measures if necessary.

Figure 1: Own illustration: Process steps of the participation procedure

Involve specialist stakeholders
With a view to the interfaces between operational hazard prevention, administration and KRITIS operators and the population, representatives of these organizations are involved in the process in order to identify potential for optimization in the interface work with the population and to work out support options for self-help for further development. This step is essential for integrating the various stakeholders into the municipal emergency response system.

Synthesis of results
The synthesis of results is to be understood as an intermediate step in which the findings from the public participation process are brought together with the perspectives of the specialist stakeholders. In addition to the comparison with the requirements resulting from the process, a comparison is made with best practice examples and lessons learned from the scientific review of the 2021 floods and from research projects in recent years that have dealt with strengthening the population's ability to help themselves. In conjunction with the findings from the relevant reviews, the proposed solutions will be used to derive measures that can contribute to supporting self-help in the specific local situation.

Feedback
In order to continue the public participation process and go beyond mere information, the final phase of the process involves feedback from all those involved in the process to date. In this step, the challenges and positive aspects identified are linked to concrete proposals for solutions and measures. This step is linked to the possibility of making further additions and including a prioritization of implementation.
In defining the process steps, this approach refers to the levels of the participation pyramid model (see Straßburger and Rieger, 2019). Various levels of participation are used here. The World Café workshop method was used as part of the Involving the population process step to document

which aspects were particularly challenging from the participants' perspective and which processes worked well under the circumstances. This methodological part was supported by a reference to the PAAG procedure from safety engineering.
Key words were defined that enable a qualitative classification of the functioning of certain processes against the background of the experience gained. For example, with regard to the provision of information by the respective municipalities, it was possible to classify whether the typical expectation was not met or the desired behavior was not achieved, or whether elements of the desired behavior were replaced by something else.
Within this framework, population groups were involved that were either affected themselves during the floods or were actively involved in neighbourhood assistance within the framework of organized structures (informal and formal). Participants were mainly recruited via the municipal administration and by approaching organized structures. This methodological step was based on the first stage of the participation pyramid and corresponds to the preliminary stages of obtaining opinions and obtaining lifeworld expertise (see Figure 2). This procedure was repeated in a second workshop with specialist stakeholders. Here, representatives of the BOS, the administrations and the infrastructure operators were involved. In this step, there was an additional focus on considering the interface with the population and analyzing the limits of their own performance. In both workshop formats, the final step was to discuss which findings could be transferred to other scenarios. As part of the qualitative data analysis, similarities and differences in the results were identified. Building on this, the results were translated into concrete implementation approaches using already established concepts and ideas for improvement developed during the workshops (see synthesis of results). A further workshop, in which the participants of the previous workshops were involved, made it possible to map participation levels four (allow co-determination/participate in decisions) and five (partially relinquish decision-making authority/use freedom of self-responsibility) in accordance with the participation concept according to Straßburger/Rieger. As part of the feedback process step, the synthesis of results was discussed and the implementation of specific measures to strengthen resilience and the guiding principle of "built back better" was developed and agreed.

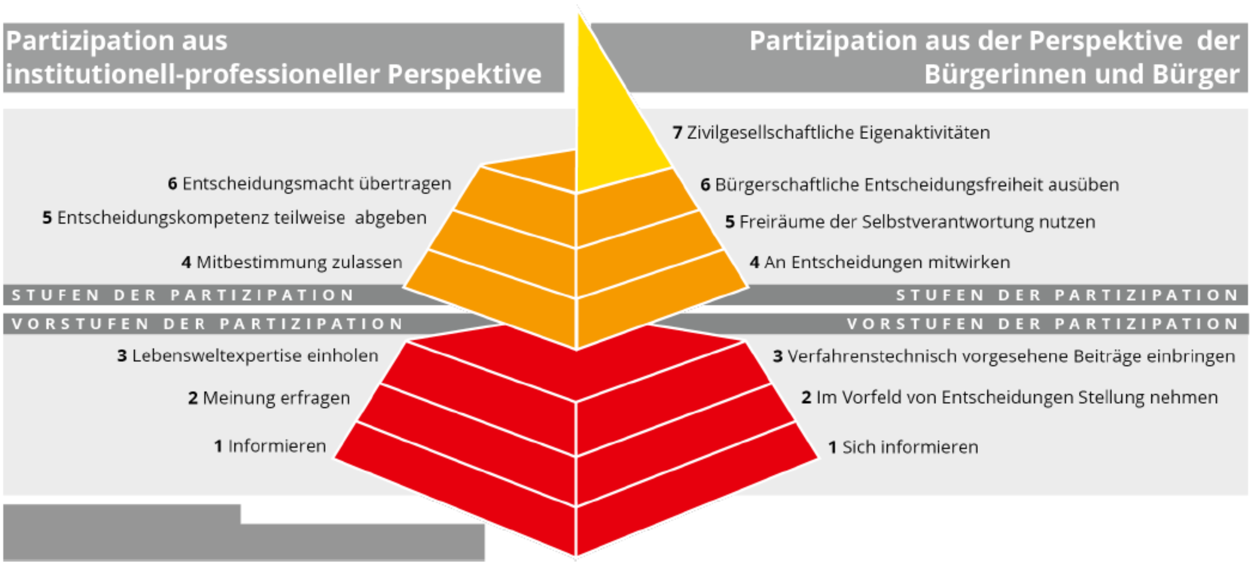


Figure 2: Participation pyramid according to Strassburger and Rieger Source: Strassburger/ Rieger (ed.) Partizipation kompakt, 2014, p. 232

In addition to reviewing experiences, the participation process outlined is intended to strengthen acceptance, understanding and participation in the measures developed (see Enke and Reinhardt, 2015; Stegert and Klagge, 2015)

Results

The results presented below are intended to provide an insight into the collected spectrum and illustrate the process of deriving measures, also based on identified best practice examples and findings from the 2021 floods. The results represent a synthesis of findings from various events held as part of municipal projects that were carried out as part of consultancy projects. The results presented here are a categorized summary of the findings of the process. They primarily serve to illustrate the connection between the results of the first participation stages and the operational-ization, i.e. the transfer of the results into concrete measures, some of which are also based on already established concepts. The results are based on the process steps "Involving the population" and
"Involving specialist stakeholders". In line with the workshop methodology, the results are summarized in
divided into the categories "positives" and "challenges".

Positive

Mutual support/neighborly help
The evaluation of the process steps made it clear that support in the communities and social networks was the key strength in dealing with the situation. This aspect played a role both from the perspective of the affected population and in the cooperation with the BOS.

Provision of equipment and materials by third parties
The ability to draw on equipment, materials and expertise from companies and private individuals was particularly helpful in cases where operational emergency response was unable to provide support in the first phase due to the prioritization of deployment sites.

Helpfulness of external parties
As there was a great willingness to help from external parties, a lot of support was provided by spontaneous initiatives. Both in the first phase and in the days that followed, the large number of helpers meant that a great deal could be absorbed.

Challenges

Communication and information was not sufficient
The majority of those involved stated that in the current situation, the lack of up-to-date information and communication from the authorities has led to a lack of clarity and uncertainty about further developments.

Interrupted power supply and communication channels
The interrupted power supply in combination with the failure of the mobile network and the communication structure was a compounding factor in the lack of information leading to uncertainty. In addition, it was not possible for a period of time to submit situation reports or transmit support

requests. This aspect was identified both from the perspective of the population and by representatives of emergency organizations.

Lack of central meeting places and contact points
Especially after the chaos phase, it was a challenge that there were no fixed points of contact and defined meeting points for networking and coordinating the clean-up work and offers of help, so that the potential could not be fully exploited and the exchange was not centrally regulated.

Coordination and management of care and assistance
It was criticized that there were no structures in place to manage and coordinate the support offered and that there was no meaningful prioritization of volunteer positions.

Lack of clarity about responsibilities and contact persons
Both in terms of official responsibilities and local coordination, there was a lack of defined contact persons who could provide information or have an overview of the overall local situation. In addition, the reporting channels, responsibilities and contact persons within the administrations were not fully defined and clarified.

Lack of knowledge about preparation and behavior in an emergency
A lack of knowledge among the population about the interpretation of warnings and the correct behavior as well as personal emergency preparedness led to an avoidable number of people in need of help, resulting in a higher burden for emergency services and the coping system.

Discussion and operationalization

Based on the results of the participation process, it is necessary to derive measures that adequately address the identified challenges and take up and strengthen the aspects identified as supportive. The aim is to ensure that the developed adaptations to the municipal emergency response system meet with acceptance and are realistically implementable by means of comprehensible and interlocking proposals for measures. The aim of operationalization is to combine the identified aspects in such a way that central measures can address several aspects or contribute to strengthening individual mechanisms.
In this example, the following measures are suitable for dealing with the challenges identified in a more targeted manner in the future:

Installation of disaster control lighthouses
As part of the research program Research for Civil Security, a concept was developed and tested in the research project "Disaster control lighthouses as contact points for the population in crisis situations", which defines contact points for the population in crisis situations. The disaster control lighthouses designed as part of the project are facilities (stationary or mobile) that ensure communication and information options for the population and operational emergency response, particularly in the event of a prolonged power outage. This includes the ability to make emergency calls, receive information from the staff and enter information (cf. Bohne et al., 2015). Based on the results of the workshops, the establishment of disaster control lighthouses can address several challenges. In
First and foremost, their installation can ensure that communication is guaranteed and that information can flow in different directions.

The provision of information in the event of a crisis can make a significant contribution to guiding behavior, preventing further damage and providing clear information and recommendations for action in terms of good crisis communication (see BMI, 2014; Pölzl-Viol, 2022; Cannaerts, 2021). In addition, disaster control lighthouses as defined contact points offer the security of being able to send out support requests and enable coordination between the various players. Regardless of the specific examples examined here, there are ideas and recommendations for adapting crisis management in response to the 2021 floods by setting up contact points supplied with emergency power to ensure the ability to communicate (e.g. Broemme, 2023). In terms of integrated planning, it should be emphasized that disaster control lighthouses represent an important interface between the population and the municipality as well as the operational emergency response and can thus support cooperation and coordination.

Establishment of resilience centers

Mutual support and help within the population was a key ability that contributed to coping. The provision of material and the willingness of outsiders to help (so-called spontaneous helpers) can also be attributed to this area. In this context, it was also noted that there was a lack of coordination and control as well as networking opportunities in order to fully exploit the potential of the willingness to help. Neighborhood help and the involvement of spontaneous helpers played a central role in coping with the 2021 floods in other places (Fekete et al., 2022). This is where the establishment of resilience centers comes in. Resilience centers are contact points for the population in crisis situations that can support coordination and networking in the sense of neighborhood assistance. The starting point here is that by setting up such
centers can support networking by providing buildings with emergency power supplies that can serve as a central point of contact for networking and coordinating help. The idea here is that this networking and coordination arises from the population itself and that different services can be created depending on the skills and support available. It can also ensure that there are central points of contact to which the population and spontaneous helpers can turn with requests for help and offers of assistance. Ideally, people from the local population will emerge to take responsibility for coordination. The civil protection information and interaction points developed as part of the Berlin project also start at these points and are a good example of how to implement contact points for networking (Ohder et al., 2015). The need to create such contact points is also underlined by research on the integration of spontaneous helpers into the civil protection system (cf. Drews et al., 2019; Carius and Steinitz, 2019). This is because managing and channeling offers of help is central to the effective use of willingness to help in terms of crisis management. Resilience centers can strengthen and structure the potential of neighborhood help and the great willingness to help in future crises.

Focus on risk communication for disaster prevention

Not only the workshops carried out, but also findings from other assessments and projects show that it is necessary to better inform the population about existing risks and to address personal emergency preparedness (e.g. DKKV, 2022). Knowing the correct behavior in certain situations can also help to prevent damage. A population that is informed about risks is in a position to make decisions appropriate to the situation. A well-prepared population can relieve the burden on the emergency services and increase coping capacities (cf. BBK, 2022b). The population's ability to protect itself and help itself is an important component of a resilient society. Well-developed social networks and good contacts in the neighborhood are an important basis for strengthening

the population's resilience to crises. Through good networking, mutual support can contribute to being able to fall back on help from one's own or local network when coping with a crisis. Raising the population's awareness, preparing for certain situations and building up knowledge about how to behave in an emergency is a key competence in terms of self-help potential. Consistent and long-term information and communication about risks and recommended behavior can create the basis for increasing awareness of threats and how to deal with them. The networking of the population in coping with a crisis is supported by self-help centers. In the area of prevention, the importance of networking should be emphasized and supported.
A central component of risk communication must be information about the defined points of contact (disaster control lighthouses and resilience centers) and the options for preparation. It is important not only to communicate general recommendations, but also to focus on local risks, preparation measures, support options and participation options. This results in the need to develop a municipal concept for risk communication that incorporates general principles as well as the specific results of the recovery (cf. BBK, 2022b).

Conclusion: open issues and challenges

The comparison of the measures developed with research projects that have already been carried out suggests that the specific experiences can be transferred to future crises and have led to comparable results (e.g. Bohne et al., 2015; Carius and Steinitz, 2019). This indicates that the approach implemented is suitable for involving the population in local planning and drawing conclusions for future events from the experience gained. It makes sense to give the participation of the population a central role in integrated hazard prevention planning. The potential that lies in the structured coordination of self-help appears to be great. The aspect of relieving the burden on operational emergency response can increase the efficiency of the local system and contribute to more effective assistance in major emergencies. Nevertheless, the findings must be placed in the context of the current situation. The high frequency of crisis situations in Germany in recent years has led to a particular awareness among the population of the effects and actual occurrence of certain crises. This currently opens up a window of opportunity that offers the chance to use the current sensitization in politics and society and to transfer starting points to future crises. However, this aspect also presents challenges for public participation procedures in hazard prevention planning. It is unclear whether it will be possible to maintain risk awareness in the medium and long term, regardless of what has been experienced
and to achieve continuous participation and assumption of responsibility (cf. 13
1 V1.1:Integrated emergency response planning - population in the focus of crisis dementia).
Furthermore, it remains to be seen whether the political will for structured preparation and participation of the population will remain as strong as it currently is, even in the case of abstract future threats. Irrespective of these challenges, it seems expedient to consider the population as an active part of hazard prevention planning in future planning and to focus on the interfaces in the municipal hazard prevention system at all levels with the aim of maintaining awareness of preparation and participation in the long term. Furthermore, it makes sense to initiate a continuous process in the sense of self-efficacy, which also involves the population in the cycle of integrated risk and crisis management.

Literature

Auswärtiges Amt (2023): Nationale Sicherheitsstrategie: Wehrhaft. Resilient. Nachhaltig. Integrierte Sicherheit für Deutschland. Berlin: Auswärtiges Amt.

B˘alteanu, Dan & Andra Costache (2009): „INVOLVING THE POPULATION IN ENVIRONMENTAL CHANGE AND EXTREME EVENTS VULNERABILITY ASSESSMENT THEORETICAL REMARKS AND CASE-STUDIES". In: Human Geographies-Journal of Studies and Research in Human Geography, S. 5–11.

BBK, Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (2022a): BBK, DFV und Vfdb Wollen Fähigkeiten Der Menschen in Selbstschutz Und -Hilfe Stärker Fördern.– (2022b). Risikokommunikation. Ein Handbuch für die Praxis. Bonn.

BMI (2014): Leitfaden Krisenkommunikation. Berlin: Bundesministerium des Innern und für Heimat (BMI).– (2022). Deutsche Strategie zur Stärkung der Resilienz gegenüber Katastrophen. Bundesministerium des Innern und für Heimat (BMI).

Bohne, P., A. Solarek, M. Surma, R. Zückmante, N. Franke, C. Hemmert-Seegers, F. Kircher, C. Lawrenz, T. Leitert & I. Schwenzien (2015): „Katastrophenschutz-Leuchttürme Hilfe Für Bürgerinnen Und Bürger Bei Stromausfällen Aus Der Perspektive von Praxispartnern". .n: *Bevölkerungsschutz* 3/2015.

Broemme, Albrecht (2023): „Unwetterereignis im Sommer 2021 – Strategien für NRW". In: Crisis Prevention, S. 72–77.

Cannaerts, Nele (6. Apr. 2021): „Crisis Communication in Public Emergencies: Multistakeholders' Perspectives". In: International Journal of Emergency Services 10.1, S. 112–130.

Carius, Christine & Daniel Steinitz (2019): „Wege zur Lagebewältigung mit Spontanhilfe". In: Crisis Prevention.

DKKV (2022): Die Flutkatastrophe Im Juli 2021 in Deutschland. Ein Jahr Danach: Aufarbeitung Und Erste Lehren Für Die Zukunft. DKKV-Schriftenreihe Nr. 62. Bonn.– (2023). Resilienz | DKKV. Deutsches Komitee Katastrophenvorsorge. https://dkkv.org/themenseiten/resilienz/ (besucht am 09. 07. 2023).

Drews, Patrick, Rebecca Nell, Franziska Wössner & Arieta Thaqi (2019): „Der Tätigkeitenkatalog als Hilfsmittel zur Integration von Spontanhelfenden in den Bevölkerungsschutz". In: Enke, Nadja und Isabel Reinhardt (2015). „Akzeptanz durch Beteiligung". In: Akzeptanz in der Medien- und Protestgesellschaft. Hrsg. von Günter Bentele, Reinhard Bohse, Uwe Hitschfeld und Felix Krebber. Wiesbaden: Springer Fachmedien Wiesbaden, S. 57–74.

Fekete, Alexander, Daniel Beckers, Chris Hetkämper, Yvonne Berger, Anne Welter, Uwe Kippnich, Alois Klemm, Maximilian Kippnich, Elias Holzheimer, Konstanze Lechner, Marc Wieland, Leonard Schliesser, Martin Gonder, Finn Moritz Juhl, Michael Luchtmann, Anna Müller, Moritz Sebastian Schüßler & Peter Priesmeier (2022): Die Flut Im Juli 2021. Erfahrungen Und Perspektiven Aus Dem Rettungsingenieurwesen Und Katastrophenrisikomanagement. Hrsg. von Karsten Fehn, Alexander Fekete, Chris Hetkämper, Alex Lechleuthner, Ompe Aimé Mudimu und Ulf Schremmer. Integrative Risk and Security Research - 1/2022. 81 S.

Gerhold, Lars (2012): „Risikobewusstsein: Sicherheit Als Konstrukt Gesellschaftlicher Wahrnehmung". In: Sicherheitskultur: Soziale Und Politische Praktiken Der Gefahrenabwehr. Hrsg. von C. Daase, P. Offermann und V. Rauer. Frankfurt am Main: Campus Verlag.

Gerhold, Lars & Agnetha Schuchardt, Hrsg. (2021): Definition von Schutzzielen Für Kritische Infrastrukturen: Forschungsstand, Rechtlicher Rahmen Und Politische Entscheidungsfindung: Forschung in Bevölkerungsschutz, Wissenschaftlicher Abschlussbericht, BBK-Projekt-Nr.:

FP 417, Abschlussdatum: 09/2019. Forschung Im Bevölkerungsschutz Band 28. Bonn: Bundesamt für Bevölkerungsschutz und Katastrophenhilfe. 489 S.

Müller, Franziska (2022): „Integrierte Planung". In: Schlüsselbegriffe Der Sozialplanung Und Ihre Kritik. Hrsg. von Mario Rund und Friedhelm Peters. Wiesbaden: Springer Fachmedien Wiesbaden, S. 89–97.

Murphy, Brenda L. (Mai 2007): „Locating Social Capital in Resilient Community-Level Emergency Management". In: Natural Hazards 41.2, S. 297–315.

Norris, Fran H., Susan P. Stevens, Betty Pfefferbaum, Karen F. Wyche & Rose L. Pfefferbaum (März 2008): „Community Resilience as a Metaphor, Theory, Set ofCapacities, and Strategy for Disaster Readiness". In: American Journal of Community Psychology 41.1-2, S. 127–150.

Ohder, Claudius, Birgitta Sticher, Sarah Geißler & Benedikt Schweer (2015): Katastrophenschutz-Informations- Und Interaktionspunkte Als Element Des Bürgernahen Katastrophenschutzes. Berlin.

Pölzl-Viol, Christiane (2022): „Besonderheiten der Risiko- und Krisenkommunikation im Strahlenschutz und radiologischen Notfallschutz". In: Bundesgesundheitsblatt - Gesundheitsforschung - Gesundheitsschutz 65.5, S. 608–614.

Schopp, Nathalie, Charline Schüler, Lynn Schüller, Tobias Hahn, Rike Richwin & Volker Tondorf (2023): „Keine Krisenbewältigung ohne Bevölkerung". In: CRISIS PREVENTION.

Shava, Soul, Marianne Krasny, Keith Tidball & Robert O'Donoghue (2010): „Local Knowledges as a Source of Community Resilience". In: Environmental Education Research 16, S. 325–339.

Stegert, Paula & Britta Klagge (2015): „Akzeptanzsteigerung Durch Bürgerbeteiligung Beim Übertragungsnetzausbau? Theoretische Überlegungen Und Empirische Befunde". In: Geographische Zeitschrift 103.3, S. 171–190.

Straßburger, Gaby & Judith Rieger, Hrsg. (2019): Partizipation kompakt: für Studium, Lehre und Praxis sozialer Berufe. 2., überarbeitete Auflage. Weinheim Basel: Beltz Juventa. 252 S.

UNISDR, United Nations Office for Disaster Risk Reduction (UNISDR) (2015): „Sendai Framework for Disaster Risk Reduction 2015 - 2030". In: S. 37.

Link to Presentation

https://thga.sciebo.de/s/bv8vA5wLQk8MBGe

Technische Hochschule Georg Agricola

Staff retention in full-time and voluntary fire departments

Philipp Toschka, Moritz Watermann

antwortING Beratende Ingenieure PartGmbB

Abstract:

Demographic change and a shortage of skilled workers are already leading to staff shortages in fire departments. In addition to measures to recruit personnel, measures to retain personnel are also required to ensure positive personnel development in the long term. The generational change in the fire departments is leading to a change in attitudes towards professional activity and volunteering and requires the individual development of suitable measures to promote staff retention. To this end, deficits with an impact on staff retention must be identified, options for action collected and concrete measures developed. These processes can be mapped in a workshop as a participation process, which also makes it easier to reach a consensus between different interest groups. In the practical implementation of the workshops, the motivational factors of *helping people / commitment*, *technology*, *training*, *support* and *appreciation* played a particularly important role. However, it is essential to identify motivational factors and obstacles individually and to develop measures based on these with the help of the firefighters.

Initial Situation

The personnel of a fire department are the central resource for achieving the level of safety defined by the municipality. For fire departments with full-time firefighters, a sufficient number of firefighters is necessary in order to be able to permanently staff the required number of functions in the emergency service at all times. In the case of purely volunteer fire departments, a high number of personnel contributes to performance in particular if this means that sufficient personnel are also available during the typical working hours of the volunteer emergency services. The need for personnel in the fire departments is expected to increase in the coming years. Three main factors will contribute to this (Deutscher Städtetag 2021):

> **New risks:** Climate change favors natural disasters such as forest fires and severe weather events in Germany (DWD 2022). In order to help with events such as the flood disaster in western Germany in 2021 or the forest fires in Meppen or Lübtheen, volunteers are often deployed to other regions of Germany for weeks at a time. As the frequency of such events increases, the relationship with the employer and (family) environment can become strained. In order to avoid this and at the same time maintain the volunteer system of civil protection, a high number of firefighters is required to ensure regular replacement of the deployed forces. Furthermore, personnel are needed for the organizational adaptation to the new risks.

Legal requirements: An increasing workload for full-time firefighters, particularly in the rescue service, combined with the implementation of the EU Working Time Directive, is leading to a growing need for personnel in shift work (Sieber et al. 2020). There are also increasing requirements in the administrative and back-office areas, for example due to the implementation of inspection regulations.

Increasing workload and changing range of operations: In addition to the rescue service, the range of operations of fire departments in fire protection and technical assistance is also changing. Apart from vegetation fires and severe weather events, there is no clear trend towards increasing deployment figures. However, due to early fire detection methods such as fire alarm systems and home smoke detectors, false alarms account for a higher proportion of the deployment spectrum than fire operations. Particularly in large municipalities without (sufficient) full-time firefighters, this can contribute to a decline in the motivation of volunteer firefighters. Full-time firefighters are therefore required more frequently to deal with day-to-day operations involving so-called "minor incidents" and to relieve the burden on volunteer firefighters.

Digitalization and automation, for example through drones, are also finding their way into fire departments. However, it is unlikely that digitalization and automation will significantly reduce the need for emergency personnel in the near future (Delmerico et al. 2019, Dirk Aschenbrenner quoted from Schinkels 2023).

In order to ensure a sufficient number of personnel in the full-time and volunteer ranks, it is therefore essential to continuously recruit and train new firefighters. To this end, measures have been taken at state and federal level in recent years to draw attention to the full-time and honorary positions in Germany's fire departments (Innenministerium NRW 2017). However, recruiting personnel is only one component of sustainable personnel development. At the same time, it is important to retain personnel in the medium to long term for full-time or voluntary work in the fire department. However, increasingly larger hurdles must be overcome to achieve the necessary personnel retention, which must first be identified within the fire department in order to be able to counter these with suitable measures.

Frequent obstacles to staff retention have been identified in the literature:

- **The compatibility of family, career and volunteering**: As firefighters get older, their family and professional responsibilities often increase, which is why the time required for operational and training duties as well as for training and further education is often no longer available (Gazzale 2019: 216; Catino 2015: 101-102; Lantz and Runefors 2021: 36; McLennan et al. 2009: 45). However, demographic change makes it necessary for firefighters to continue their volunteer work later in life.
- **Problems within the leadership and internal conflicts:** Conflicts with other firefighters and managers as well as perceived deficits in the leadership organization are a frequent cause for the termination of volunteer work in the fire department (Smith 2014: 114; Catino 2015: 103-105; Lantz and Runefors 2021: 36). This results in an outflow of personnel that could possibly be avoided by improving leadership training and conflict resolution skills.

Generational change as a current and future challenge for staff retention

With the suspension of compulsory military service in 2011 and the accompanying abolition of alternative service in the volunteer fire department, the increasing ageing of the population due to demographic change and the shortage of skilled workers on the labor market, local authorities are facing challenges in recruiting personnel for full-time or voluntary work in the fire department. A look at the statistics of the German Fire Service Association (DFV) on the development of membership figures in volunteer fire departments shows that the number of volunteer firefighters declined between 2000 and 2017 (DFV 2020). While the number of active members in the volunteer fire departments in Germany was still around 1.07 million in 2000, this had fallen to 0.994 million by 2017. In response to the declining membership figures, various advertising campaigns were carried out at state and federal level to promote full-time and voluntary work in the fire departments. Since 2018, the number of volunteer firefighters has risen again to 1.007 million in 2020, which is initially a positive development. In contrast, the shortage of full-time firefighters is steadily increasing, with the result that various professional fire departments and volunteer fire departments with full-time staff are already facing staffing restrictions (Tagesschau 2009). As this is an almost nationwide problem, municipal fire departments are increasingly competing with each other when it comes to recruiting personnel (Gräfling 2011: 335). Staff turnover and the resulting need to retain personnel are therefore relevant issues for fire departments.

Demographic change has already been identified as a key factor in the shortage of personnel. Due to the age structure of people in Germany, there are increasingly fewer people of an age at which they can participate in the fire department (Höhn et al. 2008: 10). Along with demographic change, there is a generational shift that will have a direct impact on staff retention (Mahmoud et al. 2021: 194; Anderson et al. 2017: 245).

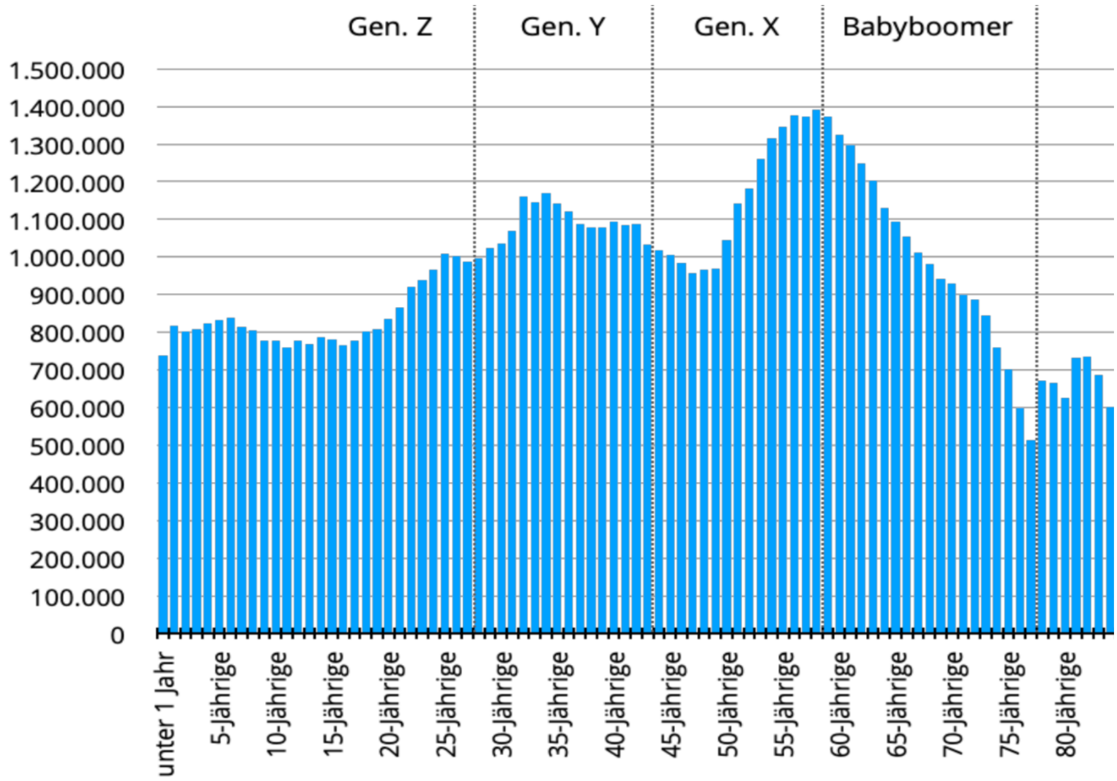


Figure 1: : Age structure of the population in Germany (Data source: Federal Statistical Office (Destatis) 2023)

In line with the age structure of the population in Germany (Figure 1), the baby boomer generation (born between 1946 and 1964) is increasingly leaving the age bracket for full-time or voluntary work in the fire department. In the social sciences, the baby boomer generation is characterized by a high work ethic, a strong sense of duty and strong loyalty to their employer (Mangelsdorf 2019: 22). The subsequent Generation X (born between 1965 and 1979) is also characterized by a pronounced loyalty to the employer (Kothapalli and Swetha 2018: 99). However, individuality is also increasingly coming to the fore in this generation. In both generations, taking up a voluntary or full-time position in the fire department usually results in a lifelong commitment.

In Generation Y, the millennials (born between 1980 and 1995), there is an increasing contrast to the previous generations. The loyalty of Generation Y to the employer is described as temporary and *economized*, i.e. loyalty is maintained as long as it is compatible with the interests of the employee (Voelpel 2007: 10). These interests include a good working atmosphere, work-life balance, the assumption of responsibility and recognition by the organization (Wunderlin 2021: 65). For work in the fire department, this means that, in case of doubt, it will also be terminated if the interests of the firefighter are not sufficiently fulfilled over a longer period of time.

Generation Z (birth cohorts from 1996 onwards) is characterized by a constant desire for change (Racolța-Paina and Irini 2021: 78). At the same time, they are considered volatile in terms of their attitude to life and work. Even if the willingness to volunteer is sometimes higher than in previous generations, this is put on hold or abandoned if it cannot be reconciled with other interests or other voluntary activities are perceived as more important. For full-time emergency personnel, this means that a change of employer is considered at an early stage if the conditions elsewhere appear more attractive. For Generation Z, steep hierarchies are at odds with their desire for co-determination and participation.

A comparison of the generations shows that the individuality of the person and the desire for participation and co-determination are increasingly coming to the fore. If these and other framework conditions are not considered to be fulfilled, younger generations in voluntary work are more willing to change the direction of their commitment or, in case of doubt, to let it rest. In the case of full-time volunteers, this is the equivalent of moving to another municipality or even to a different line of work. These characteristics should therefore be taken into account when promoting staff retention.

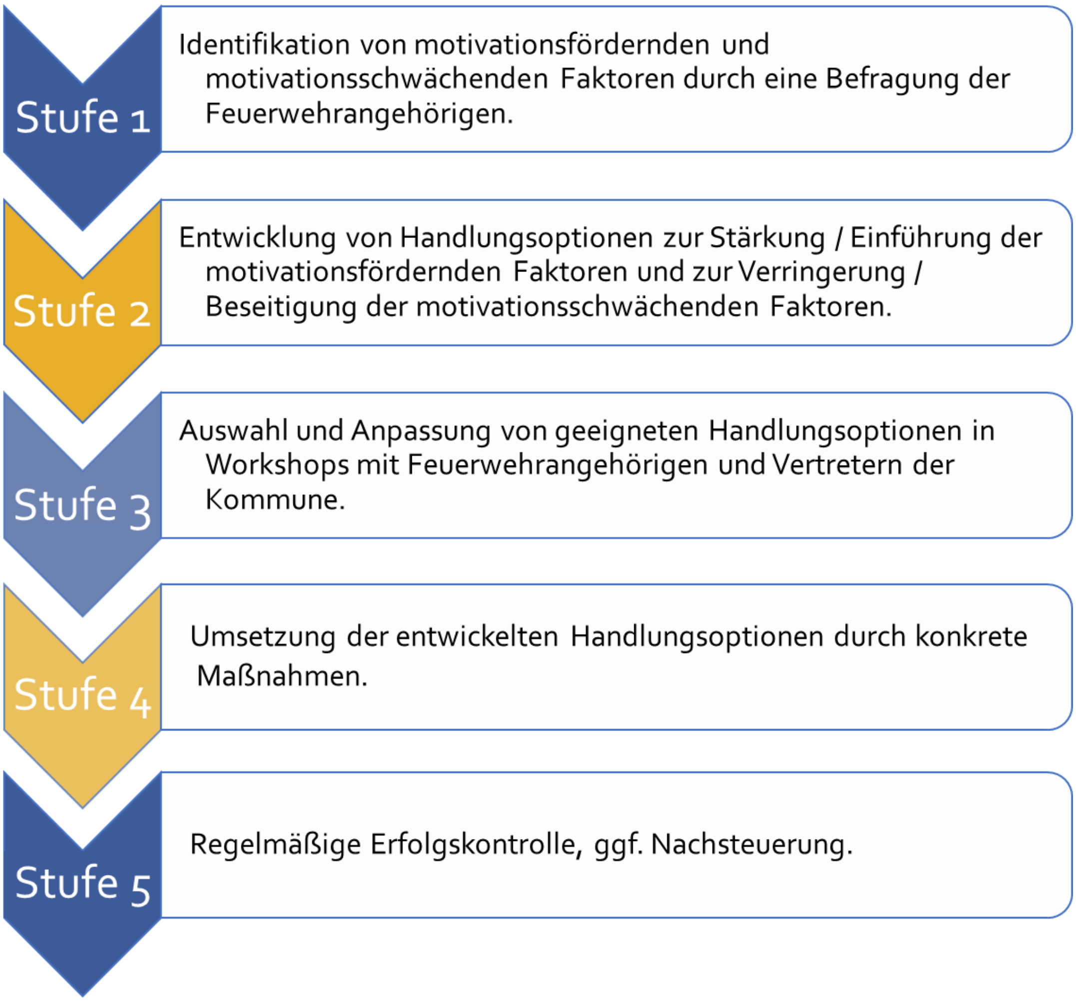
Extrinsic incentives to improve staff retention in voluntary work

A large number of different incentives to retain personnel in volunteer fire departments are already being practiced throughout Germany. These include, for example, discounted admission to municipal facilities and events, increased consideration in the allocation of building sites and in recruitment procedures, and the payment of expense allowances (Wolf 2019: 6). However, the extrinsic incentives mentioned only improve motivation in the short term and are therefore generally considered a weak tool for retaining members in fire departments (Smith 2014: 100). However, they express the municipality's appreciation of the volunteer firefighters and should in any case be designed in such a way that the firefighters do not suffer any financial disadvantages (e.g. due to travel costs) as a result of their commitment.

Firefighters should be involved in the decision as to whether and to what extent these incentives for the fire department are provided or financed by the municipality. Direct monetary incentives in particular can also be undesirable, for example, as they run counter to the firefighters' understanding of their voluntary commitment as a service to the community and the population.

Participation as a basis for promoting staff loyalty

As extrinsic incentives alone do not guarantee sufficient member retention, the intrinsic motivation of firefighters must be strengthened as part of staff retention. As part of consulting projects for municipalities, the five-stage process shown in Figure 2 has proven successful in promoting staff retention, which ensures the direct involvement of firefighters. Stages 1 to 3 can also be combined in a single workshop.



Figute 2: Five-stage participation process to strengthen staff loyalty

Implementation of the participation procedure in practice

In the course of updating the fire protection requirements plan of a large district town in North Rhine-Westphalia, a participation process for all full-time and volunteer members of the fire department was carried out and evaluated by an external consultant. A workshop in the World Café format was held as an opportunity for participation. Heterogeneous small groups were formed from all members of the fire department. The workshop format enabled a dynamic work process to be established within the small groups. This ranged from the identification of deficits with an impact on personnel retention to the development of several possible options for action, the selection of an option for action and the concrete development of measures. Conducting a workshop in a world café format made it possible for the participants to actively contribute to the development of individual measures to improve staff retention and to help shape them. This enabled the participation of all generations within the fire department, taking into account the changing needs of younger generations (Sidorcuka and Chesnovicka 2017: 813). The formation of heterogeneous small groups consisting of full-time and volunteer firefighters of all age groups led to an exchange of opinions and ideas, which made it much easier to reach a consensus.

Motivational factors for volunteering as a firefighter

The most important factors that motivate people to volunteer for the fire department are, above all, the opportunity to help other people, the community and the friendly relationship with each other, as well as the handling of technology (**Fehler! Verweisquelle konnte nicht gefunden werden.**) (Eichler 2016: 4-20; Smith 2014: 112; Gazzale 2019: 216; Lantz and Runefors 2021: 36). Problems within the community or with leadership, the compatibility of the time required with family and career and a lack of appreciation from society and politics have a particularly negative impact (Wenzel et al. 2012: 14; Landesfeuerwehrverband Bayern e.V. 2020; Catino 2015: 101-105; Lantz and Runefors 2021: 36; McLennan et al. 2009: 45).

The wide range of factors mentioned makes it difficult to define generally valid suggestions for improvement and underlines the importance of the participation process described. It also becomes clear that the two most important motivational factors in particular, the opportunity to help other people and the community within the fire department, can hardly be influenced directly. However, the workshops often provide opportunities to influence the main factors through smaller adjustments or to balance out one factor with another.

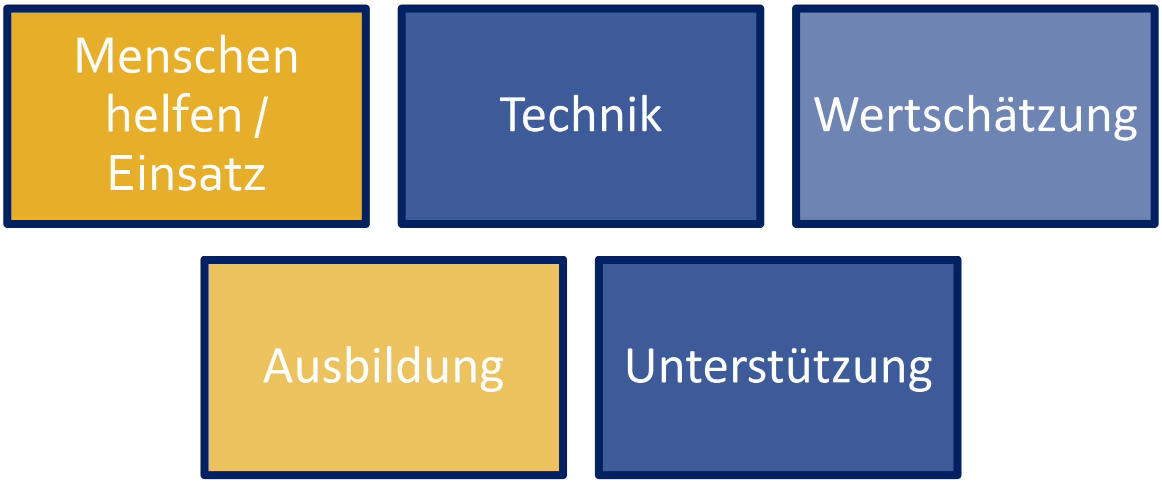


Figure 3: Motivational factors for volunteering in the fire department (adapted from Eichler 2016)

Possibilities for strengthening motivational factors in practice

The following section describes some practical ways in which factors can be influenced and the difficulties involved.

Motivation factor *Helping people / deployment*: One of the main reasons why people get involved in the fire department or can imagine getting involved in the fire department is the opportunity to help people. This arises primarily during operations. However, this also gives rise to problems. In small municipalities in particular, the number of deployments is low, but even in large municipalities, the deployments in which people are directly helped only make up a fraction of the deployment activity. On the contrary, firefighters often get the feeling that they are a nuisance, for example when fire alarms are accidentally triggered. Particularly in cities with professional fire departments or full-time firefighters, it can happen that volunteer firefighters are frequently alerted, but generally do not take action or do not even go out at all, which has a negative impact on motivation. As a remedy, the distribution of special and support tasks can be discussed in the workshop. The deployment of full-time personnel to relieve volunteer firefighters when the number of (minor) incidents is too high, on the other hand, must be thoroughly examined, and not just in terms of costs. While some volunteer fire departments welcome the deployment of full-time personnel, others see this as a threat to their participation in operations.

Motivation factor *technology*: Equipping the fire department with the latest technology (vehicle, protective clothing, fire station) not only increases its operational value, but also contributes to promoting motivation and staff retention. A careful balance must be struck here between the requirements of hazard and risk potential, the motivation of the emergency services and the financial scope of the local authority.

***Training* as a motivating factor:** In smaller fire departments in particular, training accounts for the majority of the time spent on firefighting. In order to reward firefighters for the time they spend taking part in training sessions, these should be well prepared, structured and as practical as possible. This means a considerable amount of time for the volunteer managers. Options for action include, for example, the financing of training material, the provision of suitable training objects and participation in external training events.

***Support* as a motivating factor**: The documentation and inspection workload within the fire departments has increased significantly in recent years. Options for action include the creation of administrative positions for the fire department, the hiring of full-time equipment managers or the assumption of tasks by a special-purpose association or the (rural) district.

Motivation factor *appreciation*: A perceived lack of appreciation from politicians and society is often one of the main reasons why firefighters consider ending their commitment. Options for action to increase the perceived appreciation include, for example, the fundamental implementation of measures by politicians and administration or image campaigns for the population.

Motivation of full-time emergency personnel

The type and proportion of extrinsic motivation in particular differ between full-time and volunteer emergency personnel. Even if there is a lack of meaningful studies, it can be assumed that the intrinsic motivational factors of volunteer and full-time firefighters are largely congruent. This is also due to the fact that full-time firefighters often come into contact with the fire department as a career via the volunteer fire department. In contrast to volunteer firefighters, however, the emergency service for full-time firefighters is first and foremost a profession that guarantees a sufficient income and must be reconciled with family and leisure time. Personnel retention measures for full-time emergency services personnel are therefore often based on measures that are also used in the private sector and in comparable professions. Conducting a joint workshop with full-time and voluntary staff makes it possible to reach a consensus between the two groups and identify synergies between the measures.

Summary

Demographic change and changing attitudes towards volunteering and work among the population mean that fire departments need to step up their efforts to retain personnel in full-time and voluntary positions. Whereas in previous generations, joining the volunteer fire department or starting work in the professional fire department was seen as a lifelong commitment, today's generations are moving in other directions earlier in line with their needs. The shortage of skilled workers and an increasing variety of leisure activities and opportunities for volunteering also play a part in this.

The greater willingness to change volunteering or employer should not be dismissed as a lack of motivation or stamina, as interest in full-time or voluntary work in the fire department remains high in today's generations. Instead, it should be an incentive for the municipality and the management of the fire department to improve the framework conditions within the fire department with a view to increasing staff retention. High staff retention also has an impact on the recruitment of full-time and volunteer personnel. Extrinsic incentives such as expense allowances and benefits for volunteer personnel can play a part in this and show the municipality's appreciation for the work of firefighters. However, such measures can only build on an already high level of intrinsic motivation.

The possibilities for increasing extrinsic and intrinsic motivation and the reasons for a lack of motivation are manifold. One and the same measure or framework condition can be evaluated completely differently in two fire departments. This makes a participation process for planning and implementing measures to promote staff retention absolutely essential. However, practical experience and surveys among firefighters have shown that the motivational factors of *helping people / deployment*, *technology*, *training*, *support* and *appreciation* play a particularly important role. Full-time firefighters differ from volunteer firefighters in terms of the type and proportion of extrinsic motivation in their overall motivation. A joint participation process makes it easier to reach a consensus and also makes it possible to find synergies between the interests of all those involved.

Literature

Anderson, Heather J., John E. Baur, Jennifer A. Griffith & M. Ronald Buckley (2017): What Works for You May Not Work for (Gen)Me: Limitations of Present Leadership Theories for the New Generation, in: The Leadership Quarterly 28 (1), 245-260.

Catino, James E. (2015): An Examination of Factors Influencing Retention of Volunteer Firefighters in the Commonwealth of Pennsylvania, Dissertation, Pennsylvania State University at State College.

Delmerico, Jeffrey, Stefano Mintchev, Alessandro Giusti, Boris Gromov, Kamilo Melo, Tomislav Horvat et al. (2019): The Current State and Future Outlook of Rescue Robotics, in: *J. Field Robotics* 36 (7), 1171-1191.

Destatis – Statistisches Bundesamt (2023): Fortschreibung des Bevölkerungsstandes, https://www.destatis.de/DE/Methoden/Qualitaet/Qualitaetsberichte/Bevoelkerung/bevoelkerungsfortschreibung-2021.pdf?__blob=publicationFile [15.05.2024].

Deutscher Städtetag Berlin und Köln (2021): Nachhaltige Personalgewinnung für die Feuerwehren. Positionspapier des Deutschen Städtetages Berlin und Köln, https://www.staedtetag.de/positionen/positionspapiere/2021/nachhaltige-personalgewinnung-feuerwehren [15.05.2024].

DFV – Deutscher Feuerwehr Verband (2020): Statistik des Deutschen Feuerwehr Verbandes.

DWD – Deutscher Wetterdienst & Extremwetterkongress Hamburg (Hrsg.) (2022): *Was wir 2022 über das Extremwetter in Deutschland wissen. Stand der Wissenschaft zu extremen Wetterphänomenen im Klimawandel in Deutschland*, https://www.dwd.de/DE/klimaumwelt/aktuelle_meldungen/220928/Faktenpapier-Extremwetterkongress.html [15.05.2024].

Eichler, Toni (2016): Bericht zur repräsentativen Befragung "Meinungen und Einstellungen der Bevölkerung in Nordrhein-Westfalen zur Feuerwehr", Institut für Medienforschung, Universität Siegen.

Gazzale, Laurie (2019): Motivational Implications Leading to the Continued Commitment of Volunteer Firefighters, in: *International Journal of Emergency Services* 8 (2), 205-220.

Gräfling, Wilfried (2011): Demografischer Wandel – und nun?, in: *BRANDSchutz – Deutsche Feuerwehr-Zeitung* (5), 335.

Höhn, Charlotte, Ralf Mai & Frank Micheel (2008): Demographic Change in Germany, in: Ingrid Hamm, Helmut Seitz & Martin Werding (Hrsg.), *Demographic Change in Germany*, Berlin: Springer, 9-33.

Innenministerium NRW (2017): Kampagne: Freiwillige Feuerwehr - Für mich. Für alle, https://www.im.nrw/themen/gefahrenabwehr/ehrenamt-im-brand-und-katastrophenschutz/kampagne-fuer-mich-fuer-alle [31.07.2023].

Kothapalli, Saileela & Thiruchanuru Swetha (2018): Capturing the Nature of Generations at Workplace, in: *International Journal of Advance Research and Development* 2 (11), 95-106.

Landesfeuerwehrverband Bayern e.V. (2020): Bekanntgabe der Ergebnisse zur Umfrage bei den Feuerwehrleuten und Kommandanten, https://www.lfv-bayern.de/aktuelles/bekanntgabe-der-ergebnisse-zur-umfrage-bei-den-feuerwehrleuten-und-kommandanten/ [31.07.2023].

Lantz, Emelie & Marcus Runefors (2021): Recruitment, Retention and Resignation among Non-Career Firefighters, in: *International Journal of Emergency Services* 10 (1), 26-39.

Mahmoud, Ali B., Leonora Fuxman, Iris Mohr, William D. Reisel & Nicholas Grigoriou (2021): "We aren't your reincarnation!" Workplace Motivation across X, Y and Z Generations, in: *International Journal of Manpower* 42 (1), 193-209.

Mangelsdorf, Martina (2019): *Von Babyboomer bis Generation Z. Der richtige Umgang mit unterschiedlichen Generationen im Unternehmen*, 3. Auflage, Offenbach: GABAL (Wh!tebooks).

McLennan, Jim, Adrian Birch, Sean Cowlishaw & Peter J. Hayes (2009): Maintaining Volunteer Firefighter Numbers: Adding Value to the Retention Coin, in: *Australian Journal of Emergency Management* 24 (2), 40-47.

Racolța-Paina, Nicoleta D. & Radu D. Irini (2021): Generation Z in the Workplace through the Lenses of Human Resource Professionals – A Qualitative Study, in: *Quality - Access to Success* 22 (183), 78-85.

Schinkels, Pauline (2023, 19. August): Robotik für die Feuerwehr: Wenn Wall-E Wasser wirft, in: *ZEIT ONLINE*, https://www.zeit.de/digital/2023-08/robotik-feuerwehr-waldbraende-klimakrise-munition-drohnen [07.05.2024].

Sidorcuka, Irina & Anna Chesnovicka (2017): Methods of Attraction and Retention of Generation Z Staff, in: *CBU International Conference Proceedings* 5, 807-814.

Sieber, Florian, Regina Kotulla, Bert Urban, Stefan Groß & Stephan Prückner (2020): Entwicklung der Frequenz und des Spektrums von Rettungsdiensteinsätzen in Deutschland, in: *Notfall + Rettungsmedizin* 23, 490–496.

Smith, Melanie R. (2014): Retention of Firefighters in Volunteer Fire Departments in Suburban Nebraska, Dissertation, Capella University, Minneapolis.

Tagesschau (2009, 11. September): Viele Einsätze, wenig Personal: Feuerwehren am Limit?, https://www.tagesschau.de/inland/feuerwehren-einsaetze-101.html [31.07.2023].

Voelpel, Sven (2007): *Herausforderung 50 plus. Konzepte zum Management der Aging Workforce - Die Antwort auf das demographische Dilemma*, Online-Ausg., Hoboken: Wiley (EBL-Schweitzer).

Wenzel, David, Irmtraud Beerlage & Silke Springer (2012): *Motivation und Haltekraft im Ehrenamt. Die Bedeutung von Organisationsmerkmalen für Engagement, Wohlbefinden und Verbleib in Freiwilliger Feuerwehr und THW*, Soziologische Studien 39, Freiburg: Centaurus Verlag & Media UG.

Wolf, Jochen (2019): Tagesalarmverfügbarkeit. Facharbeit, Waiblingen.

Wunderlin, Nikolas (2021): *Motivationsmodell GenZ. Motivation der Generation Z in der Arbeitswelt*, 1. Auflage, Lörrach: WME - know and learn.

Link to Presentation

https://thga.sciebo.de/s/sLkoXELpx9vkeQj

Technische Hochschule Georg Agricola

Days of Security Research

Day 3: June, 16th 2023

Session: Environment und Hygiene

Technische Hochschule Georg Agricola

Weather-induced emergency situations: Extreme data in situational awareness and visualisation

Iris Gräßler[(1)], Jens Pottebaum[(1)], Michael Hieb[(1)], Sylvia Pratzler-Wanczura[(2)], Oliver Krüger[(2)], Ivana Kruijff[(3)] und Nicola Rupp[(3)]

(1) Paderborn University

(2) Dortmund Firebrigade, Institute for Fire and Rescue technology

(3) Deutsches Rettungsrobotik-Zentrum

Abstract

Extreme weather situations increasingly lead to hazardous situations with high demands on decision-making and communication. Weather and impact forecasts serve to prepare for such an emergency situation, and extreme data must be processed during operations. Therefore, extreme data is categorised with reference to global weather data and data from local situation reconnaissance using sensors carried by mobile robots. A concept is presented in which information quality is explicitly considered in visualization for situational awareness. This extends existing principles of information visualisation with regard to the uncertainty resulting from extreme data. The results are intended to help decision-makers at different management levels to make informed decisions.

Introduction

Climate change becomes perceivable, among other things, through changed weather and increasing extreme weather situations, such as those that occurred in Western Europe in 2021 (Bundesministerium des Innern und für Heimat und Bundesministerium der Finanzen 2021). The term "extreme weather" should be understood here in the sense of "weather with potentially extreme effects". Thus, on the one hand, there is a need for long-term preparation and prevention (e. g., (Deutscher Wetterdienst et al. 2020)), or, on the other hand, an acute situation that must be treated as an emergency situation evolving over time. This results in high demands on decision-making and communication (Terti et al. 2019) as well as self-protection of the population (Gräßler et al. 2018). Weather forecasts and impact forecasts serve to prepare for such a hazard situation (e. g., (Sutanto et al. 2019)). In this article, extreme data is categorised, which in particular addresses the differentiation of global and local data in situational awareness including data from sensors carried by mobile robots. To this end, the basics are first developed and presented with reference to applications. Interdependencies with regard to information quality are derived and transferred into requirements for situation visualisation. In this way, existing basics of information visualisation are extended with regard to the uncertainty resulting from extreme data. The results can be used in all forms of geo-based situation and command information systems

Foundations

Stationary and mobile sensor systems that collect data limited to a local area are used in hazard prevention. Examples are weather stations and river gauges, but also airborne and ground-based robotic systems (UAV/UGV, see Figure 1). There are different types of data to be collected there. In the case of weather stations, these are time series from different sensors. In the case of UAV and UGV, a higher variance is possible by equipping the robots with sensors (Kruijff-Korbayova et al. 2021). With a view to optimal flight characteristics and maximum utilisation of payload, UAVs often operate integrated systems that provide, for example, video streams (H-264, MPEG-4) and photo data. However, as with UGV, configurable systems are also available here, which include, for example, thermal imaging cameras, laser scanners and hazardous material sensors. On the robotic platforms, pre-processing of streams is partly possible, so that time series or point clouds are sent in data formats such as GeoTIFF, obj or ply. Data partly refers to the actual situation in high resolution, whereby latencies in the communication have to be considered. In the case of moving sensor systems, data from the robot platform itself can also be included, describing, for example, position, orientation, joint angle or acceleration (Intertial Measurement Units, odometry) and extending measurement data with context metadata. All systems transmit with time stamps; however, synchronisation to determine a common "now" is technically challenging and can be crucial in calculations.

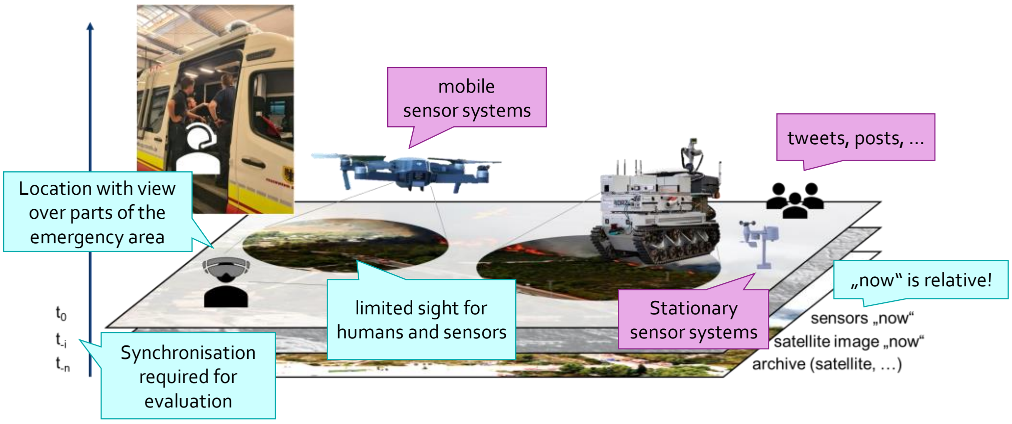


Figure 1 Collection of local data, for example by Unmanned Aerial or round Vehicles (UAV/UGV)).

In relation to extreme weather events, data services from weather services are also relevant. Available data are resolved in both spatial and temporal dimensions. However, references are not uniform and must be synchronised (see Figure 2). Depending on the weather phenomenon (heavy rain, heat waves, drought, storms etc.), the EU, for example, offers satellite-based data via the Copernicus Emergency Management System (EMS), on which current state data and forecasts with probabilities are calculated (Abily et al. 2020). These are available in frequencies from a few minutes to hours, relate to future time periods from minutes (precipitation) to months (drought) and are resolved in the meter to kilometer range. The figure indicates these dimensions in layers. Parts of the EMS services are continuously available, others are activated and provided in a hazardous situation. Weather models are initially related to weather phenomena. With regard to flood situations, the European Flood Awareness System (EFAS) provides support; with regard to forest fires, the European Forest Fire Information System (EFFIS) provides support; and with regard to soil drought, the European Drought Observatory (EDO) is to be consulted. Data are usually available in the form of geo-based raster data.

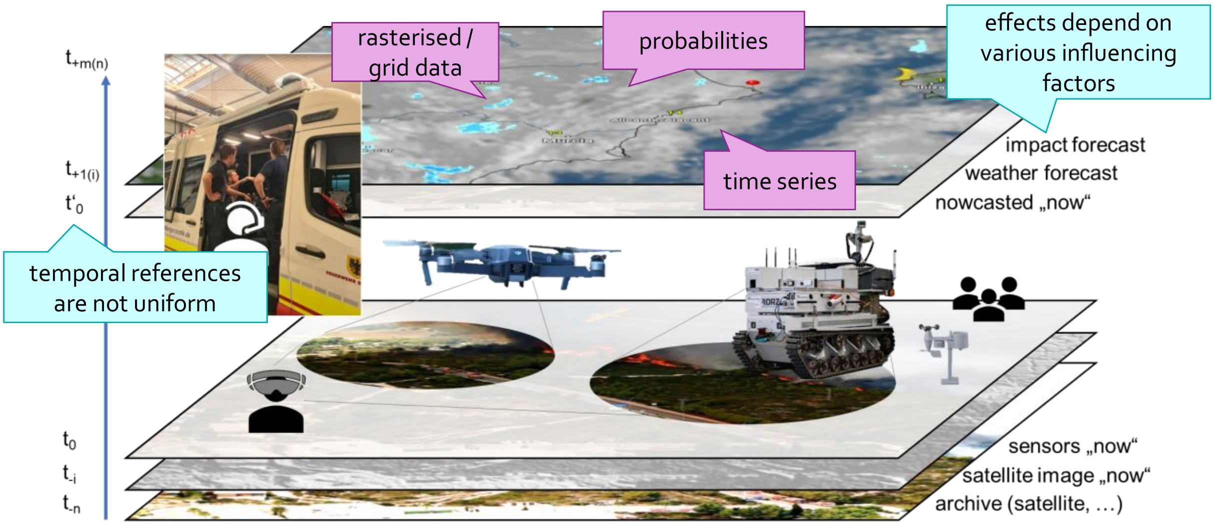


Figure 2 Consideration of global data, for example provided by national and European meteorological services.

The combination results in extreme data in terms of temporal and spatial resolution, field of view, sampling frequency and speed, heterogeneity of data formats, possible sources of error and interfering signals. The volume of data can be a challenge, but it is only one possible factor. Therefore, the term “big data” is avoided here in favour of “extreme data”.

Concept of uncertainty representation by Information Quality

Decision-makers at all levels of security management must be enabled to draw conclusions from this data. In the case of local data from sensor systems, the characteristic as “extreme data” results, for example, from the limited window of vision of the sensors that needs to be captured, diffuse environments with light and air conditions, the goodness of pre-processing algorithms and the mandatory communication channels. Global data can be obtained via the internet. Predictions are time- and space-related with probabilities. Availability is limited by licensing and legal restrictions and is partly controlled by private actors, so that not all actors may be able to act on a common data basis.

Uncertainty must therefore always be assumed. It can be represented in the form of information quality (IQ). Figure 3 shows a view from above of a geo-information system that visualises geo-based events detected in the data stream: If, for example, the detected data indicate a change in the anticipated forest fire front, the deployment of resources including sensor systems for data collection - e.g. UAVs - must be re-planned. Event detection is one example of algorithms that process data and derive decision support from it. Another example is route planners based on machine learning.

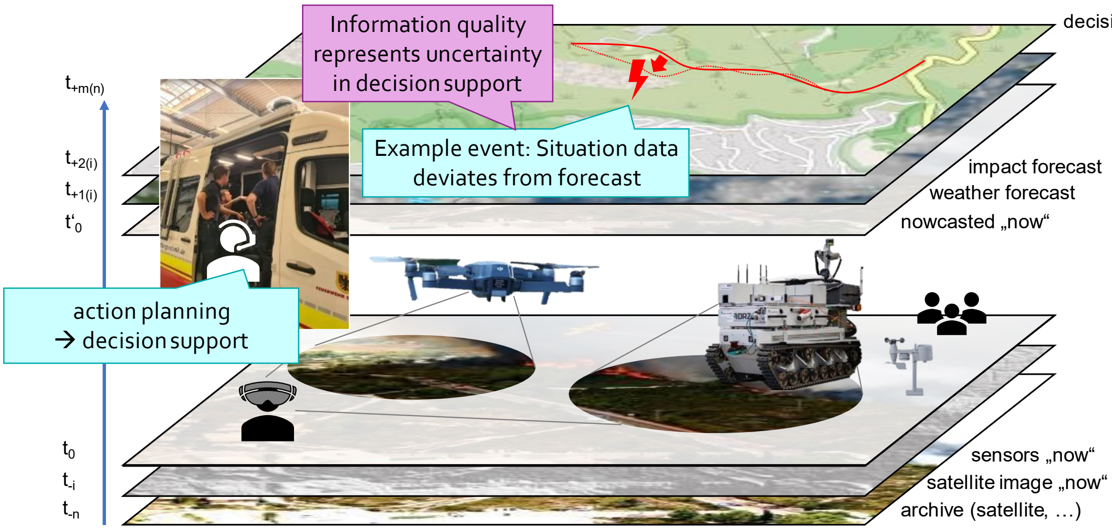


Figure 3 Example scenario: Decision support based on global and local data (map sam-ple: Open-StreetMap)

The assessment of IQ will be based on Eppler's model (2006) (cf. (Pottebaum und Gräßler 2020; Moi et al. 2015)). It is based on a literature-based synthesis of different lists of dimensions, criteria and indicators. These are brought together under the following design dimensions:

- Allocation to phases of information processing from acuqisition, verification, contextualisation to activation (cf. activities in the reconnaissance performed by actors in emergency response)
- Division into content and media (content is primarily shaped by relevance and credibility, media includes process and infrastructure)
- Differentiation into content, format and time dimension

This classification is chosen primarily because it focuses on the use of data and information (Pottebaum und Gräßler 2020). The "accuracy" of a date, for example, pays into relevance, is to be taken into account in the review phase and falls into the content dimension. The "timeliness" is a criterion for assessing credibility, is relevant at the time of activation and is in the time dimension. Accessibility is linked to infrastructure (possibly software-related), is important in the survey and belongs to the format dimension.

Depending on the type of uncertainty - expressed by a weakness in the IQ domain - decision-makers have to initiate different countermeasures or take them into account in the decision, for instance through a "plan B". For example, expert advisors may be called in to address weaknesses in content or to ensure credibility. The impact of weak accuracy, if any, can be assessed through sensitivity analyses. If data services are not accessible, a comparison with similar situations can help to at least classify an acute situation. Figure 4 illustrates this concept using two different visualisation approaches.

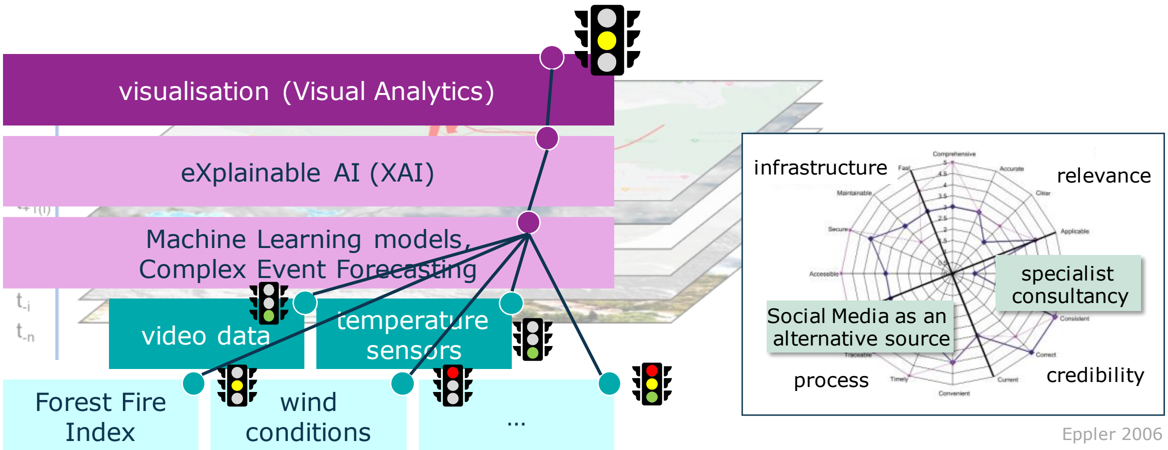


Figure 4 Levels of information processing in CREXDATA with visualisation of IQ (based on (Eppler 2006))

First, the processing levels from data at the bottom to visualised information on top of the stack are shown, as they are built up in the CREXDATA project. Temperatures, videos, forest fire index and wind conditions are mentioned as examples of data. These are processed using methods such as classification by machine-trained models or Complex Event Forecasting (cf. (Pottebaum et al. 2012)). An "explainability layer" in the sense of eXplainable AI (XAI) adds information to enrich the results of this processing with additional information that is understandable to humans. This creates the basis for applying visualisation approaches. Shown on the left is a simple traffic light system that can be used to click through from the visualisation into the depth of the processing: On which layer and at which point is the uncertainty expressed by the yellow traffic light based? In this case, it could be unknown wind conditions that make a hazardous substance dispersion calculation uncertain. Shown on the right is a detailed representation based on IQ criteria (cf. (Eppler 2006)). Depending on the characteristics in the spider diagram, a recommendation can be offered as to which countermeasures would be useful to improve the IQ.

Implementation in CREXDATA

The CREXDATA project focuses on the algorithms and technical capabilities indicated by the above layers. They are based on efficient data acquisition and include processing close to the sensor, extraction of information and its visualisation. Explainability is a crucial interface that should be thought of by the use case. Instead of technical explainability, which can be created through targeted transparency of models, solutions are to be created in which decision-makers perceive a piece of information as "sufficiently explained". The basis for the application in the field of hazard prevention is, on the one hand, rescue robotics (Kruijff-Korbayova et al. 2021) and, on the other hand, the geoinformation and decision support system ARGOS, which was built on the basis of results from the EU project ANYWHERE (Abily et al. 2020; van Lanen et al. 2019) (see Figure 5). ARGOS is used in different locations and levels of civil protection. Users include civil protection centrally in Spain, in Catalonia, in cities such as Badalona, but also in publicly or privately run institutions such as water management or the management of flood evacuation plans in campsites.

Thus, a functional basis is available to implement and test the described concepts in application scenarios.

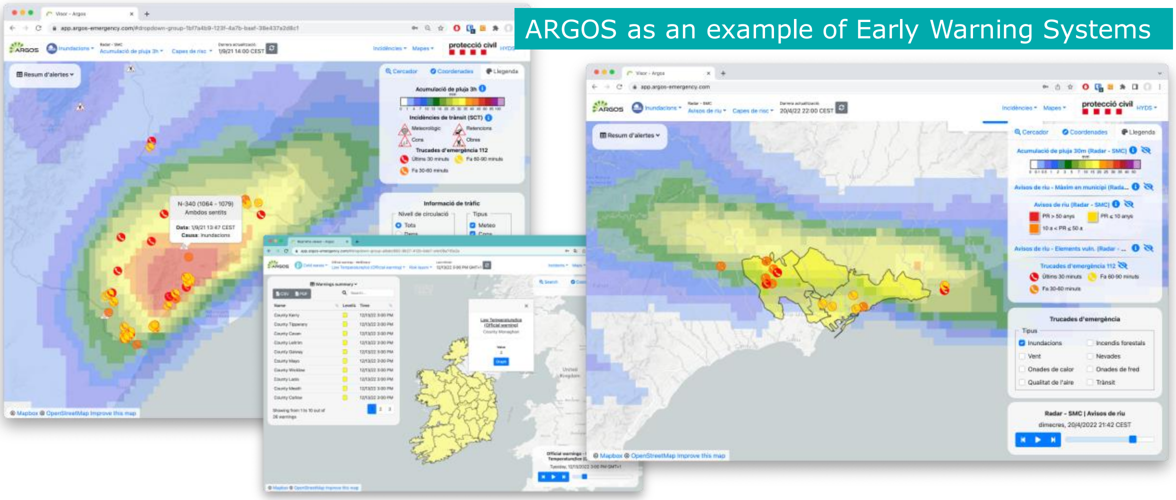


Figure 5 ARGOS as an example of a weather-related decision support system (source: HYDS, https://www.hyds.es/)

Summary

CREXDATA experiments with different technologies from machine learning and Compex Event Recognition to Complex Event Forecasting, XAI and Visual Analytics to visualisation. The starting point is "extreme data", which in this case includes local sensor data with different temporal and spatial resolutions and global data, e.g. from weather services. Interdependencies in terms of information quality are to be integrated into the situation visualisation and support the interpretation. This will extend existing foundations of information visualisation in terms of knowledge about uncertainty in extreme data. The results can be used in all forms of geo-based situation and command information systems.

Acknowledgements

The research leading to these results has received funding from the European Union's Horizon Europe Programme under the CREXDATA Project, grant agreement n° 101092749.

Literature

Abily, Morgan, Philippe Gourbesville, Eurico de Carvalho Filho, Xavier Llort, Nicolas Rebora, Alexandre Sanchez & Daniel Sempere-Torres (2020): Anywhere: Enhancing Emergency Management and Response to Extreme Weather and Climate Events, in: Guy Caignaert, Jean Cnge, Philippe Gourbesville (Hrsg.), *Advances in Hydroinformatics*, Singapore: Springer Water, 29 – 37, http://dx.doi.org/10.1007/978-981-15-5436-0_3.

Bundesministerium des Innern und für Heimat, Bundesministerium der Finanzen (2021) Bericht zur Hochwasserkatastrophe 2021: Katastrophenhilfe, Wiederaufbau und Evaluierungsprozesse, https://www.bmi.bund.de/SharedDocs/downloads/DE/veroeffentlichungen/2022/abschlussbericht-hochwasserkatastrophe.pdf?__blob=publicationFile&v=1 [31.03.2023].

Rauthe, Monika, Christoph Brendel, Martin Helms, Anne-Farina Lohrengel, Lennart Meine, Enno Nilson, Maike Norpoth et al. (2020): Klimawirkungsanalyse des Bundesverkehrssystems im Kontext Hochwasser: Schlussbericht des Schwerpunktthemas Hochwassergefahren (SP-103) im Themenfeld 1 des BMVI-Expertennetzwerks, https://doi.bafg.de/BfG/2020/ExpNRM2020.2020.04.

Eppler, Marin J. (2006): *Managing Information Quality. Increasing the Value of Information in Knowledge-intensive Products and Processes.* Berlin/Heidelberg: Springer, https://doi.org/10.1007/3-540-32225-6.

Gräßler, Iris, Jens Pottebaum & Philipp Scholle (2018): Influence Factors for Innovation in Digital Self-Preparedness Services and Tools, in: *International Journal of Information Systems for Crisis Response and Management* 10 (1), 20 – 37, https://doi.org/10.4018/IJISCRAM.2018010102.

Kruijff-Korbayova, Ivana, Robert Grafe, Nils Heidemann, Alexander Berrang, Cai Hussung, Christian Wilms, Peter Fettke et al. (2021): German Rescue Robotics Center (DRZ): A Holistic Approach for Robotic Systems Assisting in Emergency Response, in: *Proceedings of the 2021 IEEE International Symposium on Safety, Security, and Rescue Robotics (SSRR)*, 138 – 145, https://doi.org/10.1109/SSRR53300.2021.9597869.

Moi, Matthias, Therese Friberg, Robin Marterer, Christian Reuter, Thomas Ludwig, Deboarh Markham, Mike Hewlett et al. (2015): Strategy for Processing and Analyzing Social Media Data Streams in Emergencies, in: *Proceedings of the 2nd International Conference on Information and Communication Technologies for Disaster Management (ICT-DM)*, 42 – 48, https://doi.org/10.1109/ICT-DM.2015.7402055

Pottebaum, Jens & Iris Gräßler (2020): Informationsqualität in der Produktentwicklung: Modellbasiertes Systems Engineering mit expliziter Berücksichtigung von Unsicherheit, in: *Konstruktion* 72 (11-12), 76 – 83.

Pottebaum, Jens, Alexander Artikis, Robin Marterer & George Paliouras (2012): User-Oriented Evaluation of Event-Based Decision Support Systems, in: *Proceedings of the IEEE 24th International Conference on Tools with Artificial Intelligence. IEEE Computer Society*, 162 – 169, https://doi.org/10.1109/ICTAI.2012.30.

Sutanto, Samual J., Melati van der Weert, Niko Wanders, Veit Blauhut & Henny A.J. van Lanen (2019): Moving from drought hazard to impact forecasts, in: *Nature Communications* 10, 4945, https://doi.org/10.1038/s41467-019-12840-z.

Terti, Galateia, Isabelle Ruin, Milan Kalas, Ilona Láng, Arnau Cangròs i Alonso, Tommaso Sabbatini & Valerio Lorini (2019): ANYCaRE: A Role-Playing Game to Investigate Crisis Decision-Making and Communication Challenges in Weather-Related Hazards, in: *Nat. Hazards Earth Syst. Sci*. 19 (3), 507 – 533, https://doi.org/10.5194/nhess-19-507-2019.

Van Lanen, Henny A.J., Claudia Vitolo , Claudia Di Napoli , Samuel Sutanto, Mirko D'Andrea, Tuomo Bergman, Enrico Duo et al. (2019): A pan-European multi-hazard early warning system: ANYWHERE MH-EWS, in: Geophysical Research Abstracts 21.

Link to Presentation

https://thga.sciebo.de/s/owD5HK2qhvbuLgq

Technische Hochschule Georg Agricola

Rescue, Extinguish, Recovery, and (Environmental) Protection – The follow-up care in the fire department is gaining increasing importance

Bernhard Glittenberg

private

Abstract

The increasing presence of plastics and composite materials in private households leads to an increase in potentially hazardous substances in the event of a fire. Firefighting water releases toxic, carcinogenic, and environmentally harmful substances from smoke gases. The firefighting water enters soils, surface or groundwater, and the public sewer system. Various legislations generally regulate the handling of contaminated waters, often without direct reference to firefighting water, by referring to threshold values. The study examines the environmental hazard of firefighting water in relation to legal regulations. The firefighting water exceeds threshold values for more than 80% of the recorded parameters, thus posing a threat to soils, groundwater, and surface water. The threshold values for discharge into the public sewer system were met by 90%. The next step is to assess the contamination of soils by firefighting water.

Legal Framework, Guidelines, and Recommendations

On October 14, 1992, the Firefighting Water Retention Directive (LöRüRL) came into force in North Rhine-Westphalia (NRW). This directive regulated the handling of firefighting water for the first time in a binding manner. The directive stipulated the capacity of firefighting water retention devices and under what conditions and at which storage sites firefighting water retention should take place. The decisive factor was the proportion of water-hazardous substances within the storage facility. The aim of the LöRüRL was the precautionary principle of water law according to § 19 g paragraph 1 WHG and the associated protection of water. The directive supplemented the building code (BauO) and the Federal Immission Control Act (BImSchG). Furthermore, changes were made to various regulations such as TRGS 514 (09/1987), TRbF 100 (03/1989), and guidelines from VdS, VCI, and IPS. The LöRüRL excluded facilities where water-hazardous substances were used but not stored and was defined as "obsolete" by the German Institute for Construction Technology (DIBt) on January 1, 2020, and "suspended" (LöRüRl 2003). Other references in other regulations remained in place.

As a supplement to the LöRüRL, the Regulation on Installations Handling Hazardous Substances and Specialist Companies (VAwS) came into force in March 2004. This regulation for the first time regulated the handling of hazardous substances in installations and specialist companies. For example, Section 10 of the VawS regulated retention in wastewater facilities in the event of leaks or operational disruptions. Firefighting water retention was not included in this regulation (VawS 2003).

The Regulation on Installations Handling Hazardous Substances came into force in April 2017 and was amended with a revision in June 2020. This replaced the previously valid VawS and, for the first time, regulated firefighting water retention in all installations. Installations must be planned, constructed, and operated in such a way that the water-hazardous substances, firefighting water, sprinkler water, and cooling water released during fire incidents, as well as the resulting combustion products with water-hazardous properties, are retained according to the generally recognized rules of technology (§ 20 AwSV 2020).

Specifications for firefighting water retention based on the AwSV were provided, for example, by the VCI guideline "Firefighting Water Retention" from July 2017. This guideline establishes firefighting water retention measures based on risk assessment and quantifies the required retention volume. For the storage of water-hazardous substances, the guideline refers to the LöRüRL. The basis for the assessment includes the type of building or installation and its use, the probability of occurrence, the damage and hazard potential, and the existing infrastructure (VCI 2017).

The mentioned regulations, guidelines, laws, and ordinances pertain to measures within the scope of permits for installations and storage areas. Firefighting water retention in the household or private sector is not provided for.

Further guidance on handling firefighting water can be found in the Fire Service Regulations (FwDV) 500 "Units in ABC Operations" from January 2022. ABC hazards within the framework of FwDV 500 include atomic, consisting of radiological and nuclear, biological, and chemical hazards. The service regulation aims to enable fire service personnel to recognize and counteract these hazards. In case of suspected contaminated firefighting water with ABC hazardous substances, measures to prevent the spread must be taken according to section 1.5.3.4. Generally, FwDV 500 refers to firefighting water retention or retention devices (FwDV 500 2022).

The Analytical Task Force (ATF) of the Cologne Fire Department has developed a matrix for assessing firefighting water and a process description for analyzing firefighting water. This describes the possible process of investigations in the "Analytical Roll Container." Within this analysis, firefighting water retention is required if various substances are detected above certain concentrations. These include highly toxic substances (if known), phenols, nitro compounds, simple aliphatic and aromatic components, as well as heavy metals. If the electrical conductivity of the firefighting water is three times higher than that of the water used, an assessment by the representative of the wastewater association is required after determining nitrite, nitrate, sulfate, and phosphate (Beßlich 2023/1).

Problem Statement

The use of various polymers, chemicals, and composite materials in the private sector results in a toxic smoke cocktail during both complete and incomplete combustion. Components such as chlorine, sulfur, nitrogen, phosphorus compounds, and hydrocarbons, which react due to high temperatures and varying oxygen concentrations, are released. This smoke is suppressed when extinguishing fires with the typically used firefighting water. During this process, toxic compounds are dissolved in the water, and particles carrying absorbed pollutants are carried away. Among the toxic, corrosive, and hazardous compounds are inorganic acids, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), or organic halogen compounds (vfdb 1997 and Bavarian State Office for the Environment 2011).

These compounds enter the nearby environment of the fire site with the firefighting water. The water infiltrates into soils in the home garden, onto adjacent properties, or into the sewer system. During a barn fire, water seeps into the field. There are no regulations, guidelines, or laws regarding firefighting water retention for these types of fires. Firefighting water retention is the responsibility of the incident commander. The incident commander is instructed to plan for firefighting water retention when using firefighting additives. The use of firefighting additives typically does not occur during the fully developed phase of a fire.

In the first step, the contribution within the scope of a dissertation aims to clarify the composition of firefighting water from residential and attic fires and whether the contained pollutants have the potential to harm the environment, specifically soil, and reach groundwater.

During subsequent fire remediation, the focus is usually on repairing damaged buildings and rooms. However, there is no routine examination of the surroundings of the damaged property.

In the further course of the work, the actual contamination of affected soils will be examined. This will also clarify whether the infiltration of firefighting water into the soil causes an exceedance of the threshold values of the Federal Soil Protection Ordinance as of August 1, 2023.

Investigation Methodology

For the examination of firefighting water, potential ingredients were defined beforehand based on valid regulations, ordinances, and guidelines:

- Surface Water Ordinance (OGewV); as of December 9, 2020
- Self-Monitoring Ordinance (SüwV-kom); as of May 25, 2004
- Wastewater Ordinance (AbwV); as of January 20, 2022
- Mantle Ordinance (MantelVO); as of August 1, 2023
- State Working Group Waste (LAGA); LAGA M20 as of November 6, 2003
- Local drainage regulations

To quantify and potentially consider a baseline contamination of used firefighting water due to the influence of the vehicle and materials, water samples were taken from the tanks of 16 vehicles from the years 1996 to 2021 beforehand.

The investigation parameters were divided into three categories: leading and summary parameters, inorganic contamination, and organic contamination. The examination was carried out in a laboratory certified by the German accreditation body. International (ISO), European (EN), and German (DIN) standards were applied.

Table 1: Parameter Listing of the Investigations

Parameters	Device	Standards
pH value, Electrical conductivity, temperature	Measuring electrodes	DIN EN ISO 10523 (C 5):2012-04, DIN EN 27888 (C 8):1993-11, DIN 38404-C 4:1976-12
Anions	Ion chromatography (IC) (IC)	DIN EN ISO 10304-1 (D 20):2009-07
Metals	ICP-MS	DIN EN ISO 17294-2 (E 29):2017-01
Ammonium, Cyanid, Phenol	Continius-Flow-Analysis (CFA)	DIN EN ISO 11732 (E 23):2005-05, DIN EN ISO 14403-2 (D 3):2012-10, DIN EN ISO 14402 (H 37):1999-12
TOC, TNb	TOC	DIN EN 1484 (H 3):2019-04, DIN EN 12260 (H 34):2003-12
AOX	AOX	DIN EN ISO 9562 (H14):2005-05
BTEX, LHKW	GC-MS	DIN 38407-F 43:2014-10, DIN EN ISO 10301 (F 4):1997-08
Hydrocarbons (C_{10} – C_{40})	GC-FID	DIN EN ISO 9377-2 (H 53):2001-07
PCB	GC-ECD	DIN 38407-F3:1998-07
PAK	HPLC	DIN EN ISO 17993 (F 18):2004-03

Blind Values

The firefighting water used typically consists of drinking water, surface water, or water from cisterns. The water in the collection tank of a vehicle consists mostly of tap water, as storing firefighting water from surface water sources promotes algae growth. Therefore, the investigations were based on the threshold values of the Drinking Water Ordinance (TVO).

Due to differences in construction year and design, different sampling points were used for the vehicles during the investigations. In newer vehicles, sampling was conducted at the hygiene board, while in older vehicles, samples were taken at the drainage valve of the pump, at the side outlet, or directly from the pump.

During the examination of the samples, significantly elevated levels of iron and zinc were observed in some cases. This phenomenon, mostly occurring in older vehicles, is believed to be caused by the aging of the surge walls and the fire-fighting centrifugal pump (FPN). Additionally, there was one instance of high organic contamination, where the sampling point below the vehicle was unsuitable and contaminated with grease and oil.

When comparing the leading and summary parameters to tap water, which was tested both with and without a standpipe and supply line, there were no anomalies. The threshold values of the TVO were adhered to, except in the cases described above. The mentioned anomalies were not further considered due to the relatively small amount of water in the older vehicle tanks, which had a maximum capacity of 600 liters, and the vehicles' impending decommissioning.

Presentation of Results of Firefighting Water Samples

In the examination of 18 firefighting water samples collected over the course of a year from both domestic and international sources, significant variations in the results were observed (See Table 3). This confirms that fire conditions are not identical, and the composition of the burning materials varies widely.

Table 2: Minimum and maximum values of various measured parameters – excerpt

Parameters	Min	Max	Parameters	Min	Max
pH value	6,8	9,9	**Cadmium**	0,001 mg/L	0,074 mg/L
Conductivity	316 µS/cm	4400 µS/cm	**Chrome**	0,013 mg/L	0,800 mg/L
AOX	0,018 mg/L	13,4 mg/L	**Copper**	0,04 mg/L	1,95 mg/L
TOC	2,9 mg/L	1.300 mg/L	**Nickel**	0,008 mg/L	0,354 mg/L
Hydrocarbons	0,12 mg/L	12 mg/L	**Lead**	0,012 mg/L	1,83 mg/L
Phenol	0,02 mg/L	64 mg/L	**Antimony**	0,007 mg/L	0,538 mg/L
Arsenic	0,005 mg/L	0,025 mg/L	**Tin**	n.a.[10]	
Cobalt	0,001 mg/L	0,040 mg/L	**Selenium**	0,006 mg/L	0,012 mg/L
Zinc	0,327 mg/L	40,0 mg/L	**Chloride**	21 mg/L	600 mg/L
Fluoride	0,08 mg/L	19 mg/L	**Cyanide, ges.**	0,01 mg/L	0,29 mg/L
Naphthalene	130 ng/L	21,0 µg/L	**Benz(a)pyrene**	11 ng/L	2,60 µg/L

[10] n.a. - Not applicable, measurements disrupted by matrix effects.

Table 3: Relative Standard Deviation and Mean Values of Various Measured Parameters – Excerpt

Parameters	Mean Value	Rel. Stand.dev.	Parameters	Mean Value	Rel. Stand.dev.
pH value	7,8	10 %	**Cadmium**	0,013 mg/L	140 %
Conductivity	1800 µS/cm	60 %	**Chrome**	0,140 mg/L	150 %
AOX	1,56 mg/L	220 %	**Copper**	0,30 mg/L	150 %
TOC	250 mg/L	140 %	**Nickel**	0,061 mg/L	140 %
Hydrocarbons	3,2 mg/L	110 %	**Lead**	0,47 mg/L	120 %
Phenol	6,9 mg/L	220 %	**Antimony**	0,101 mg/L	130 %
Arsenic	0,013 mg/L	60 %	**Tin**	n.a.[11]	
Cobalt	0,010 mg/L	100 %	**Selenium**	0,009 mg/L	30 %
Zinc	6,39 mg/L	180 %	**Chloride**	272 mg/L	70 %
Fluoride	4,0 mg/L	120 %	**Cyanide, ges.**	0,06 mg/L	40 %
Naphthalene	3,93 µg/L	140 %	**Benz(a)pyrene**	0,52 µg/L	140 %

The limits set by various drainage regulations in relation to the average of all firefighting water samples are met for 90% of the parameters, while for the Wastewater Ordinance (AbwV), the percentage is over 90%. The limits are exceeded in the parameters of settleable Solids, Zinc, and AOX.

In contrast, the limits of the Surface Water Ordinance in relation to the average of all firefighting water samples are exceeded for 88% of the parameters. Nitrite and Nitrate Nitrogen, as well as the pH value, were not exceeded.

[11] n.a. - Not applicable, measurements disrupted by matrix effects.

Technische Hochschule Georg Agricola

Conclusion and Outlook

The collected firefighting water samples were taken after the firefighting activities. The average amount of firefighting water used was approximately 2,500 liters. Assuming that the concentration of pollutants in the firefighting water decreases due to dilution with progressing firefighting activities, it can be inferred that the determined concentrations represent minimum values.

As the results indicate, firefighting water from fires in non-industrial buildings poses a risk to the environment. When discharging firefighting water from fires into the public sewer system, it can be assumed that in most cases, and with sufficient dilution by additional water, this is possible. However, runoff of firefighting water into surface water should be prevented in any case.

For the consideration of precautionary values of the individual pathways of the Federal Soil Protection Ordinance (BBodSchV), it can be assumed that firefighting water may have the potential to harm soil and protection goods (humans, groundwater). In the further course of the dissertation, the contamination from firefighting water in the soil will now be investigated. Soil samples will be taken from potentially contaminated areas and subjected to analysis. In this case, the preloading of the soil by other anthropogenic influences such as mining and industry must be taken into account. Another aspect is the transfer of the results to other soil types. Depending on the location of the fire site, different enrichment in the soil is expected due to the different soil structures and physical properties (Scheffer et al., 2019). Column experiments with undisturbed soil columns will also be conducted to investigate the transport of pollutants in the affected soils to assess groundwater contamination.

Finally, the question of firefighting water retention in the above-mentioned fire incidents needs to be clarified, taking into account the circumstances of the fire departments and their tasks.

Literature

§ 20 AwSV (2020). Verordnung über Anlagen zum Umgang mit wassergefährdenden Stoffen (AwSV), zuletzt geändert durch Art. 256 V v. 19.6.2020 I 1328. §20, https://www.gesetze-im-internet.de/awsv/BJNR090500017.html [23.05.2024].

Amelung, Wulf, Hans-Peter Blume, Heiner Fleige, Rainer Horn, Ellen Kandeler, Ingrid Kögel-Knabner, Ruben Kretschmar, Karl Stahr, Berndt-Michael Wilke: *Scheffer/Schachtschabel Lehrbuch der Bodenkunde*, 17. Aufl., Berlin, Heidelberg: Springer Spektrum.

Bayrisches Landesamt für Umwelt (Hrsg.) (2011): Schadstoffe bei Brandereignissen, https://www.arguk.de/leistung/gebaeude/documents/Schadstoffe-bei-Brandereignissen.pdf [06.06.2021].

Beßlich, Stefan (2023): Löschwasserbeurteilung in der Gefahrenabwehr, in: BRANDSchutz 77 (1), 24- 27.

Feuerwehr-Dienstvorschrift 500 (Januar 2022). Einheiten im ABC – Einsatz, https://www.base.bund.de/SharedDocs/Downloads/BASE/DE/rsh/4-relevante-vorschriften/4-5-FwDV500-2022.pdf [23.05.2024].

LöRüRL – Richtlinie zur Bemessung von Löschwasser-Rückhalteanlagen beim Lagern wassergefährdender Stoffe (2003), RdErl. d. Ministeriums für Bauen und Wohnen v. 14.10.1992 – II A 5 – 190.6 (am 01.01.2003: MSWKS), https://recht.nrw.de/lmi/owa/br_text_anzeigen?v_id=4820070525144953388 [23.05.2024].

VAwS – Verordnung über Anlagen zum Umgang mit wassergefährdenden Stoffen und über Fachbetriebe (2003), zuletzt geändert durch Gesetz vom 29. April 2003 (GV. NRW. S. 254), https://recht.nrw.de/lmi/owa/br_text_anzeigen?v_id=10000000000000000064 [23.05.2024].

VCI – Verband der Chemischen Industrie e.V. (2017): VCI-Leitfaden. Löschwasserrückhaltung. Juli 2017, https://www.vci.de/services/leitfaeden/vci-leitfaden-loeschwasserrueckhaltung.jsp [23.05.2024].

vfdb – Vereinigung zur Förderung des Deutschen Brandschutzes e.V. (Hg.) (1997): Schadstoffe bei Bränden. Richtlinie 10/03, https://ditzingen.de/fileadmin/Dateien/Dateien/Feuerwehr/Downloads/Ausbildung_und_Brandbekaempfung/Brandgase.pdf [06.06.2021].

Link to Presentation

https://thga.sciebo.de/s/z6EgTImRT4V1Pd1

Technische Hochschule Georg Agricola

The Decontamination of Skin from PAH with Innovative Methods.

Jonas Schubert(1,2) and Max Schnepf(1,2)

(1) DermaPurge GmbH

(2) Leibnitz-Institut für Polymerforschung

Abstract

Cleaning compositions to remove PAH from the skin have been tested in this study. They do not contain any substances that impairs the barrier function of the skin and, at the same time, exhibits outstanding decontamination performance.

Polycyclic aromatic hydrocarbons (PAH) are carcinogenic substances and are among the components found in smoke from fires. It has been known for many years that these substances in smoke can cause cancer. PAH can enter the body through respiratory, dermal and oral uptake.

Dermal absorption of PAH occurs when there is direct contact with the skin. This can happen during firefighting operations, especially during interior attacks, at the spots where the protective gear does not fully prevent skin contamination.

Until now, attempts have been made to remove PAH from the skin using soaps and soap-containing agents, such as cleaning wipes. However, it has been demonstrated that after using specialized cleaning wipes, 77% or more of the PAH remain on the skin. With soap and water 53% of the PAHs remain on the skin. Furthermore, use of current skin cleansing agents can lead to a "washing-in effect." This means that the PAH can penetrate the skin up to 400% more easily.

Introduction

Polycyclic aromatic hydrocarbons (PAH) are carcinogenic substances and present in fire smoke. The fact that these substances in smoke residues cause cancer is known for many years. (Barbosa et al., 2023) Recently, the IARC, a sub-organization of the WHO, classified the occupational group of firefighters as no longer only "possibly carcinogenic" (category 2b), but as "known to be carcinogenic" (category 1a). This is the highest possible hazard classification. This classification was largely based due to the exposure of firefighters to PAH. (Demers et al., 2022)

PAH are increasingly formed during incomplete combustion and during the burning of plastics. (Li et al., 2001) Incomplete combustion is occuring more often nowadays due to well insulated buildings. The insulation leads to a reduced air supply and vent, which favors incomplete combustion. The increasing prevalence of plastics in buildings also results in a higher amount of PAH being produced in the event of a fire.

PAH can enter the body through three routes: inhalation, dermal, and oral.

Figure 6: Results of the FAST study. In the study, model smoke containing fluorescent 2.5 µm silicate (SiO2) particles were generated and firefighters were exposed to it. Subsequently, the fluorescence was visualized using UV light. It can be seen that the protective gear is permeable, especially at the transition points. This is the case in the mask area, at the transition from jacket to gloves (arm), from jacket to pants (abdomen) and at the transition from pants to shoes (leg). (Hill, 2015)

Inhalation can be well prevented by wearing the appropriate breathing apparatus. Dermal PAH are absorbed when there is skin contamination. This occurs during fire operations, especially during inside attacks, at the transition points of the protective equipment, which does not completely prevent contamination of the skin (see Figure 6). (Hill, 2015) In a study with coke oven workers, it was shown that up to 75% of PAH are absorbed through the skin and thus enter the body. (VanRooij et al., 1993) Effective cleaning of PAHs from the skin is therefore extremely relevant - also for firefighters.

Furthermore, in the wider operational environment of a fire, there is a risk of dermal uptake through contamination carryover, e.g. through skin contact with contaminated hoses or other operational equipment. This is also important because oral uptake usually occurs as a consequence of skin contamination, namely also through contamination carryover.

Contaminated hands transfer the hazardous substances to food, for example, and thus there is an oral uptake of the PAHs into the body from a dermal contamination. Studies show that oral uptake can be as high as inhalation uptake. (Cherrie et al., 2006)

An efficient and safe decontamination of PAHs is therefore necessary. Soap or wipes which have been used so far, are not suitable for decontamination, as will be explained in the following.

State of the Art

Up to now, attempts have been made to remove PAH from the skin using soaps and soap-containing agents, such as wipes. Two points clearly speak against these methods: first, too much of the skin-resorptive PAHs remain on the skin, and second, skin permeation can even be increased.

In literature, it is shown that after cleaning with soap and water more than 56% of the PAH remain on the skin. With specialized cleaning wipes, the decontamination efficiency was even less effective: with the wipes tested, 77% or more of the PAHs remained on the skin (see ***Figure 7***). (Keir et al., 2023)

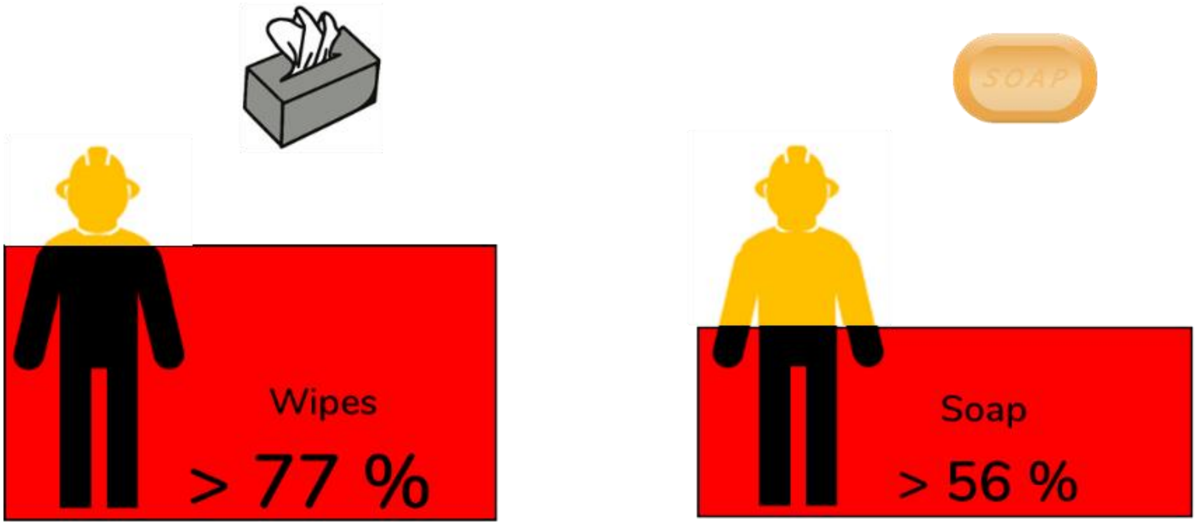


Figure 7: Cleansing performance in the literature of different skin cleansers of a PAH contamination. When wipes are used, 77% and when soap is used, 56% of the PAH remain on the skin. (Keir et al., 2023) In addition, all known wipes and skin cleansers contain substances that can damage the skin barrier and thus increase penetration through the skin. (Moody et al., 1995) Soaps and decontamination wipes should not be used immediately after fire operations for these reasons.

One reason that could explain the less cleaning efficiency is that these products are not designed for the cleaning of PAH and only for the optical effect of the cleaning. This, however, in the case of soot and PAH can be misleading. Soot is black whereas PAH are colorless (cf. Figure 8). This can lead to the impression that an optical clean skin is also free from PAH, which is not the case.

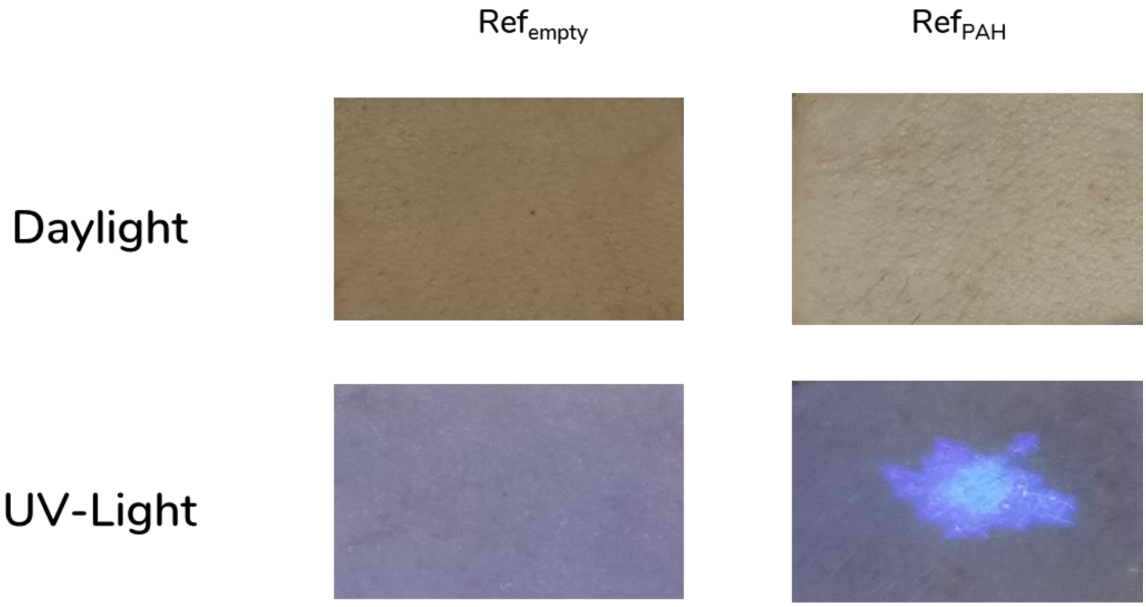


Figure 8: Pig skin samples under normal light and under UV light. Contamination with PAHs is only visible under UV light.

Secondly, the use of previously used skin cleansing agents is not only ineffective, but it is even counterproductive, because soaps or soap-containing agents, which are also contained in decontamination cloths, lead to a washing-in effect. This describes the process of impaired skin barrier due to the usage of skin cleaner with penetration enhancers. The PAHs can then penetrate the skin up to 400% more easily (see Figure 9). (Moody et al., 1995)

Examples of such penetration enhancers can be found on the ingredient list of many skin cleansers and decontamination wipes used to date, such as Alcohol denat, (Williams and Barry, 2004) Aloe Barbadensis extract, (Cole and Heard, 2007) Caprylic/Capric Triglyceride, (Leopold and Lippold, 2011) Cetylpyridiniumchlorid, (Som et al., 2012) Chamomilla Recutita Extract, (Johnson et al., 2018) Citric Acid, (Prasanthi and Lakshmi, 2012) Cocamidopropyl Betaine, (Pandey et al., 2014) Coco Glucoside, (ElMeshad and Tadros, 2011) Disodium Cocoyl glutamate, (Okasaka et al., 2019) Glycerin, (Williams and Barry, 2004) Propylene Glycol, Isopropyl Alcohol, (Williams and Barry, 2004) Lactic Acid, (Copoví et al., 2006) Limonene, (Chen et al., 2016) Linalol, (Chen et al., 2016) PEG-40 Hydrogenated Castor Oil, (Burnett et al., 2014) Polysorbat 20, (Akhtar et al., 2011) Sodium Cocyl Glutamate, (Okasaka et al., 2019) Sodium Lauryl Sulfate, (Som et al., 2012) Vitamin E. (Trivedi et al., 1995)

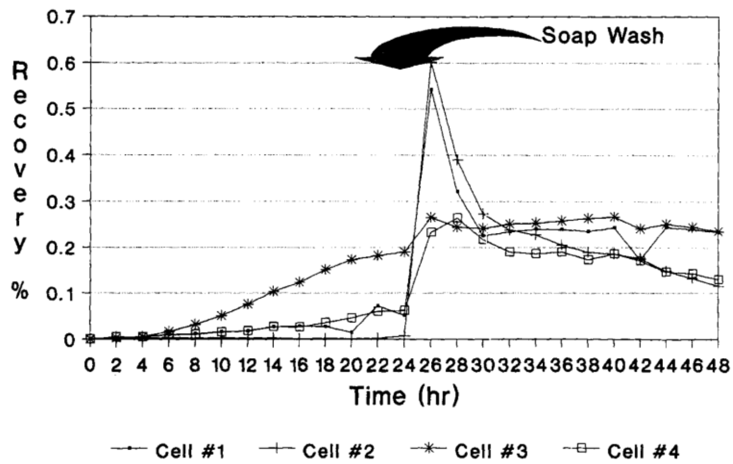


Fig. 4. In vitro analysis of ^{14}C-B[*a*]P permeating 32-year-old ♀ human skin. The % recovery in the receiver solution is shown versus time for each of the four replicate Bronaugh cells. The onset of the 24-h skin wash with Radiac soap and water is shown.

Figure 9: Wash-in effect. The use of soap can increase the uptake of PAHs through the skin by up to 400%.(Moody et al., 1995)

Furthermore, for the decontamination of hazardous substances, cold water should be used. This is important because water that is too warm (above 32°C) also opens the pores and increases the absorption of PAHs. (Wood et al., 2012)

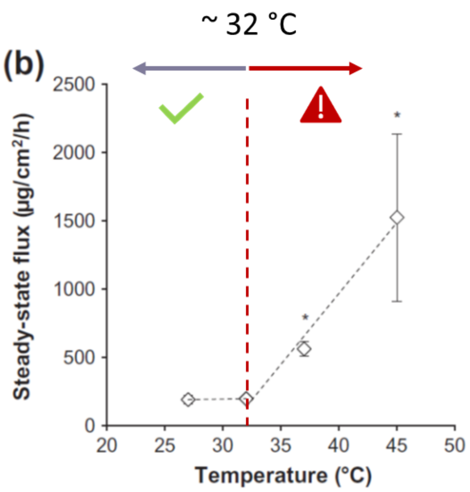


Figure 10: Temperature dependence of skin penetration. Skin penetration increases from 32°C. Adapted from (Wood et al., 2012).

A suitable decontamination agent should be penetration enhancer free, effective and usable with cold water. To the best of our knowledge, there is no product on the market and nor any other solutions published that fulfill these requirements.

Methods

General manufacturing process of the decontamination compositions:

In a first step, at least a water-soluble polymer was mixed with purified water. Then, at least one phyllosilicate was homogenized and after homogenization added to the mixture. The mixture was thoroughly stirred until homogenization. Further described is the representative manufacture of 100 g of a gel: 5 g of Soybean protein isolate were mixed with 75 g of purified water (18.2MΩ). 10 g of bentonite and 10 g of kaolin were homogenized and then added to the mixture of the protein isolate in water. The completed mixture was thoroughly stirred until homogenization.

General design of the decontamination experiments:

Decontamination experiments were performed with porcine skin. Pigs of the German Landrace are used, aged between 5 and 8 months. Pieces of skin of approximately 10 cm x 10 cm were removed from the area of the lateral abdominal wall with the help of a scalpel. A distance of at least 5 cm from the spinal column, ribs and the middle of the abdomen were maintained. The pieces of skin were wrapped in surgical drapes to avoid contamination with subcutaneous fatty tissue. The transport to the laboratory was carried out in freezer bags in a cool box at approx. 4-8 °C on cooling batteries or ice.

First, the skin surface was cleaned with lukewarm water. Then the preparation base was covered with a layer of aluminium foil and above that a layer of absorbent material (e.g., Zemuko universal compress). A piece of skin was placed on top of this with the stratum corneum side down. Artery clamps were attached to the four corners of the skin, and the skin was stretched by means of the rubber bands. Alternatively, the skin was fixed with four needles which were inserted through the skin corners into a polystyrene pad. The subcutaneous fatty tissue was grasped with surgical tweezers and separated directly below the dermis with a scalpel. Care had to be taken that no contact of the surface with subcutaneous fat occurred. Due to the risk of contamination, the outermost 5 mm in the marginal area had to be discarded after the subcutaneous fat tissue had been dissected. The prepared skin was then placed on the aluminum foil with anatomical tweezers, smoothed if necessary, and wrapped in aluminum foil and placed in a freezer bag. The freezer bag was sealed as airtight as possible. The skin was frozen at -20 °C to -30 °C in the freezer on a flat surface. For further use, the samples were stored in the freezer for at least 24 hours. The maximum storage period was 6 months. Before use in the experiments, the skin pieces were hydrated. For hydration, a beaker with acceptor medium was tempered to 32 °C. The skin pieces were then placed in the beaker and completely covered by the acceptor medium.

Decontamination experiments

Skin samples were contaminated with either fluorene (f) or benzo[a]pyrene (b), which are typical model systems for PAH. Stock solutions were prepared as follows: (f) = fluorene: 2.2 mg/mL in chloroform, (b) = benzo[a]pyrene: 3.3mg/mL in chloroform.

Due to their fluorescence, the PAHs were quantitatively well detectable. After an exposure time of 30 seconds after contamination, appropriate countermeasures were taken. These were thorough rubbing with the prepared decontamination composition and subsequent washing with cold water. All pieces of skin were examined in a fluorescence spectrometer. The concentration of PAHs was chosen to avoid self-quenching of fluorescence. The skin was then washed with cold water. Although PAHs are not visible to the naked eye, they become so in the ultraviolet range because they absorb ultraviolet light and then fluoresce (see Figure 8).

Thus, the efficiency of the compositions could be determined with 2D-resolved fluorescence spectroscopy (Tecan M200 Infinite Pro Microplate Reader) and compared with the performance of other skin cleansers. At least 25 points on each skin piece were evaluated. In order to avoid that self-fluorescence of the skin has an influence on the measured efficiency, one untreated skin (Ref_{empty}) and one skin piece without washing (Ref_{PAH}) were used as reference.

The removal of soot was tested optically and documented via photographs.

Results

For the evaluation of the different cleaning compositions, the decontamination compositions were prepared by mixing. The compositions are shown in Table 1. Afterwards the cleaning experiments were conducted.

The evaluation of different cleaning compositions and of commercial products is displayed in table 1.In order to avoid that self-fluorescence of the skin has an influence on the measured efficiency, one untreated skin (Ref_{Empty}) and one skin piece without washing (Ref_{PAH}) were used as reference.

The washing efficiency (E) is defined as:

$$E = 100 - \frac{100 * (Sample - Ref_{empty})}{(Ref_{PAH} - Ref_{empty})}$$

Table 1: The decontamination efficiency of different compositions. The content of the different cleaning compositions are shown as well. Highlighted in orange are commercial products that contain penetration enhancer.

No.	Dekontaminationseffizienz (E), %	Entfernt Ruß	Inhaltsstoff 1	wt%	Inhaltsstoff 2	wt%	Inhaltsstoff 3	wt%	Inhaltsstoff 4	wt%
1	100 (b)	-	BSA	10	activated carbon	10	Kaolin	10	Bentonite	10
2	61.7 (b)	-	Poloxamer 407	10	activated carbon	10	Kaolin	10	Bentonite	10
3	82.3 (f)	+	Soybean protein isolate	5	Bentonite	10	Kaolin	10	-	-
4	80.4 (b)	-	Soybean protein isolate	5	Bentonite	10	Kaolin	10	activated carbon	10
5	97.2 (b)	+	Soybean protein isolate	5	Bentonite	10	Kaolin	10	-	-
6	94.9 (f)	+	Bentonite	15	Kolliphor®P407	8	Kaolin	12	-	-
7	86.8 (b)	+	Bentonite	15	Kolliphor®P407	8	Kaolin	12	-	-
8	53,5 (b)	-	Roquette DS112	2	activated carbon	10	Kaolin	10	Bentonite	10
9	58,7 (b)	-	Chitosan	2	activated carbon	10	Kaolin	10	Bentonite	10
10	95,8 (b)	-	pak-ex	100						
11	76.0 (b)	+	Kommerzielles Produkt, das folgende Inhaltsstoffe enthält, C_{16-20} isoalkane, Juglans regia shell powder, sodium laureth sulfate, sulfated castor oil, sodium chloride, cocamidopropyl betaine, quaternium-18 bentonite,							

			titanium dioxide, PEG-4 rapeseed amide, potassium sorbate, cellulose gum, sodium benzoate, citric acid.							
12	60.0 (b)	+	Handseife							
13	0 (b)	-	Kommerzieles Dekontaminationsmittel, das Wasser und polyvalente Inhaltsstoffe besitzt							
14	5.0 (f)	-	Wasser							

In previous experiments we found that bentonite and kaolin have a beneficial effect on the cleaning efficiency of hazardous substances. That is why we included these substances in the compositions for the decontamination experiments as well. Table 1 shows that the usage of phyllosilicates is beneficial for the decontamination efficiency. Different additives were added to the phyllosilicate compositions: Roquette DS112, Poloxamer 407, BSA and Soybean protein. Interestingly soybean helped to remove soot, whereas BSA did not show an enhancement soot cleaning.

We found decontamination efficiency from 0-100%. Interestingly, a commercial agent, that is advertised as a decontamination agent against chemicals, showed the lowest decontamination efficiency of 0%. Also this agent could not remove soot from the skin. Other commercial products which are not advertised as contamination agents were better in the efficiency (60-76%), but still not very good. This is in accordance with other publications. (Keir et al., 2023) However they are not suited for the decontamination of skin, as they consist of soap or other penetration enhancer.

Conclusion

It was possible to find different compositions which are suitable for the removal of PAH and soot from the skin.

After fire fighting, a shower should be taken as soon as possible, preferably still at the scene of the incident. Since this is not possible for many firefighters, the most vulnerable skin areas should be decontaminated roughly. According to studies (see Figure 6), these are the hands and the transition areas of the protective clothing (face, neck, abdomen, shins), where the highest PAH concentrations were found after a fire. To reach all contaminated skin areas, showers should also be taken as soon as possible after gross decontamination.

It is important not only for firefighters, but also for everyone involved in the fire operation, to thoroughly clean themselves of PAHs afterwards. They may all have come into contact with these carcinogenic substances, either through a cloud of fire smoke or through contact with contaminated equipment (e.g. hoses).

These new developments are essential for these occupational groups, because previous cleaning agents fail to clean PAHs and aggravate their harmful effect on health. Although this mechanism is known, it has so far been consistently ignored in the manufacture of decontamination agents - in view of the lack of alternatives. In the presented new compositions, there are no substances that would impair the barrier properties of the skin.

Literature

Akhtar, Naveed, M.U. Rehman, H.M.S. Khan, Fatima Rasool, Tariq Saeed & Ghulam Murtaz (2011): Penetration Enhancing Effect of Polysorbate 20 and 80 on the in Vitro Percutaneous Absorption of Lascorbic Acid , in: *Tropical Journal of Pharmaceutical Research* 10 (3), 281-288, DOI: 10.4314/tjpr.v10i3.1.

Barbosa, Fernandu Jr., Bruno A. Rocha, Marilia C. O. Souza, Mariana Z. Bocato, Lara F. Azevedo, Joseph A. Adeyemi, Anthony Santana & Andres D. Campiglia (2023): Polycyclic Aromatic Hydrocarbons (Pahs): Updated Aspects of Their Determination, Kinetics in the Human Body, and Toxicity, in: *Journal of Toxicology and Environmental Health*, Part B, 26 (1), 28-65, DOI: 10.1080/10937404.2022.2164390.

Burnett, Christina L., Bart Heldreth, Wilma F. Bergfeld, Donald V. Belsito, Ronald A. Hill, Curtis D. Klaassen, Daniel C. Liebler, James G. Marks jr., Ronald C. Shank, Thomas J. Slaga, Paul W. Snyder & F. Alan Andersen (2014): Safety Assessment of PEGylated Oils as Used in Cosmetics, in: I*nternational Journal of Toxicology* 33 (4), 13-39, DOI: 10.1177/1091581814546337.

Chen, Jun, Qiu-Dong Jiang, Ya-Ping Chai, Hui Zhang, Pei Peng & Xi-Xiong Yang (2016): Natural Terpenes as Penetration Enhancers for Transdermal Drug Delivery, in: *Molecules* 21 (12), 1709, DOI: 10.3390/molecules21121709.

Cherrie, John W., Sean Semple, Yvette Christopher, Ahsan Saleem, Greame W. Hughson & Andrew Philips (2006): How Important is Inadvertent Ingestion of Hazardous Substances at Work?, in: *The Annals of Occupational Hygiene* 50 (7), 693-704, DOI: 10.1093/annhyg/mel035.

Cole, Louise & Charles Heard (2007): Skin Permeation Enhancement Potential of Aloe Vera and a Proposed Mechanism of Action Based Upon Size Exclusion and Pull Effect, in: *International Journal of Pharmaceutics* 333 (1-2), 10-16, DOI: 10.1016/j.ijpharm.2006.09.047.

Copoví, A., O. Díez-Sales, J.V. Herráez-Domínguez & M. Herráez-Domínguez (2006): Enhancing Effect of Alpha-Hydroxyacids on "In Vitro" Permeation Across the Human Skin of Compounds With Different Lipophilicity, in: *International Journal of Pharmaceutics* 314 (1), 31-36, DOI: 10.1016/j.ijpharm.2006.01.033.

Demers, Paul A. , David M. DeMarini, Kenneth W. Fent, Deborah C. Glass, Johnni Hansen, Olorunfemi Adetona, Maria H. G. Andersen, et al. (2022): Carcinogenicity of Occupational Exposure as a Firefighter, in: *The Lancet Oncology* 23 (8), 985-86.

ElMeshad Aliaa Nabil & Mina Ibrahim Tadros (2011): Transdermal Delivery of an Anti-Cancer Drug via W/O Emulsions Based on Alkyl Polyglycosides and Lecithin: Design, Characterization, and In Vivo Evaluation of the Possible Irritation Potential in Rats, in: *AAPS PharmSciTech* 12, 1-9, DOI: 10.1208/s12249-010-9557-y .

Hill, Jay (2015): Fluorescent Aerosol Screening Test (FAST), RTI International, http://responderwipes.com/wp-content/uploads/2016/07/RTI_Test_Report-FAST-Jan2015.pdf [24.05.2024].

Johnson Wilbur jr., Ivan Boyer, Wilma F. Bergfeld, Donald V. Belsito, Ronald A. Hill, Curtis D. Klaassen, Daniel C. Liebler, James G. Marks, Ronald C. Shank, Thomas J. Slaga, Paul W. Snyder, Lillian J. Gill & Bart Heldreth (2018): Amended Safety Assessment of Chamomilla recutita-Derived Ingredients as Used in Cosmetics, in: *International Journal of Toxicology* 37 (3), 51-79, https://doi.org/10.1177/1091581818801814.

Keir, Jennifer L. A., Tracy L. Kirkham, Rocio Aranda-Rodriguez, Paul A. White & Jules M. Blais (2023): Effectiveness of Dermal Cleaning Interventions for Reducing Firefighters' Exposures to PAHs and Genotoxins, in: *Journal of Occupational and Environmental Hygiene* 20 (2), 84-94, DOI: 10.1080/15459624.2022.2150768.

Leopold, Claudia S. & Bernhard C. Lippold (2011): An Attempt to Clarify the Mechanism of the Penetration Enhancing Effects of Lipophilic Vehicles with Differential Scanning Calorimetry (DSC), in: *Journal of Pharmacy and Pharmacology* 47 (4), 276-81, DOI: 10.1111/j.2042-7158.1995.tb05795.x.

Li, Chun-Teh, Huan-Kai Zhuang, Lien-Te Hsieh, Wen-Jhy Lee & Meng-ChunTsao (2001): PAH Emission From the Incineration of Three Plastic Wastes, in: *Environment International* 27 (1), 61-67, DOI: 10.1016/s0160-4120(01)00056-3.

Moody, Richard P., Brita Nadeau & Ih Chu (1995): In Vivo and in Vitro Dermal Absorption of Benzo[a]pyrene in Rat, Guinea Pig, Human and Tissue-Cultured Skin, in: *Journal of Dermatological Science* 9 (1), 48-58, DOI: 10.1016/0923-1811(94)00356-j.

Okasaka, Mana, Koij Kubota, Emi Yamasaki, Jianzhong Yang & Sadaki Takata (2019): Evaluation of Anionic Surfactants Effects on the Skin Barrier Function Based on Skin Permeability, in: P*harmaceutical Development and Technology* 24 (1), 99-104, https://doi.org/10.1080/10837450.2018.1425885.

Pandey, Anushree, Ashu Mittal, Nitesh Chauhan & Sanjar Alam (2014): Role of Surfactants as Penetration Enhancer in Transdermal Drug Delivery System, in: *J Mol Pharm Org Process Res* 2 (2), 2-7.

Prasanthi, Domaraju & P. K. Lakshmi (2012): Effect of Chemical Enhancers in Transdermal Permeation of Alfuzosin Hydrochloride, in: *ISRN Pharmaceutics* 2012, 965280, DOI: 10.5402/2012/965280.

Som, Iti, Kashish Bhatia & Mohd Yasir (2012): Status of Surfactants as Penetration Enhancers in Transdermal Drug Delivery, in: *Journal of Pharmacy and Bioallied Sciences* 4 (1), 2-9, DOI: 10.4103/0975-7406.92724.

Trivedi, Jay S., Steven L. Krill & James J. Fort (1995): Vitamin E as a Human Skin Penetration Enhancer, in: *European Journal of Pharmaceutical Sciences* 3 (4): 241-43, https://doi.org/10.1016/0928-0987(95)00014-5.

VanRooij, J. G., M. M. Bodelier-Bade & F. J. Jongeneelen (1993): Estimation of Individual Dermal and Respiratory Uptake of Polycyclic Aromatic Hydrocarbons in 12 Coke Oven Workers, in: *British Journal of Industrial Medicine* 50 (7), 623-632, https://oem.bmj.com/content/50/7/623.

Williams, Adrian C. & Brian W. Barry (2004): Penetration Enhancers, in: *Advanced Drug Delivery Reviews* 56 (5), 603-18, DOI: 10.1016z/j.addr.2003.10.025 .

Wood, D. G., M. B. Brown & S. A. Jones (2012): Understanding Heat Facilitated Drug Transport Across Human Epidermis, in: *European Journal of Pharmaceutics and Biopharmaceutics* 81 (3), 642-649, DOI: 10.1016/j.ejpb.2012.03.019 .

Link to Presentation

https://thga.sciebo.de/s/I3HXrs8jQIsXv4r

Technische Hochschule Georg Agricola

Days of Security Research

Day 3: June 16th 2023

Session: Poster-Session

Technische
Hochschule
Georg Agricola

Note:

The Poster Session includes eight scientific Poster. These are offered for free download.

The link leads to the Science Cloud SCIEBO of the Federal State North Rhine Westphalia. By using the link, users agree to be redirected to external sources. The publisher accepts no responsibility for links in the presentations.

Note:

The Conference language was German. Thus, the poster are German.

Teleoperierte Erkundung von Krisen- und Gefahrensituationen durch multimodale Verknüpfung von Sensortechnologien. | Teleoperated exploration of crisis and hazardous situations through multimodal linking of sensor technologies.

Christoph Kölbl, Jonas Grzesiak, Daniel Häfele, Frank Duschek, Bernhard Linseisen, Maximilian Durner, Tobias Hecking

Download Poster

Georisiken – Georessourcen – Ein Einblick | Georisks - Georesources - An insight

Tobias Rudolph

Download Poster

UAV-getragenes Laserspektroskopie-System zur aktiven Ferndetektion von Gefahrstoffen auf Oberflächen. | UAV-mounted laser spectroscopy system for the active remote detection of hazardous substances on surfaces.

Christoph Kölbl, Jonas Grzesiak, Daniel Häfele, Frank Duschek

Download Poster

Drone4SitA | Drones for Situation Awarness – Wie können Drohnen zur Lagedarstellung beitragen? | Drone4SitA | Drones for Situation Awarness - How can drones contribute to situational awareness?

Bodo Bernsdorf, Heiner Rössmann

Download Poster

Technologien und Anwendungen von Infrarot-Imagern in der Sicherheitstechnik – Stand der Technik und Perspektiven | Technologies and applications of infrared imagers in safety engineering - state of the art and perspectives

Marvin Daniel Michel

Download Poster

Erkundung von Großschadenslagen | Reconnaissance of major emergencies

Konrad Barth, Tobias Emanuel Gleibs, Thomas Säger,
Lennart Walter Landsberg, Ompe Aimé Mudimu

Download Poster

Katastrophenschutz und bergbaulichen Bodenbewegungen – Geowissenschaften in der Anlagensicherheit | Disaster prevention and mining ground movements - Geosciences in plant safety

Benjamin Haske, Tobias Rudolph, Bodo Bernsdorf

Download Poster

Anwendung des Spektralindex "Normalized Burn Ratio" (NBR) auf die Beobachtung von Waldbränden | Application of the spectral index 'Normalised Burn Ratio' (NBR) to the observation of forest fires

Marcin Pawlik, Bodo Bernsdorf

Download Poster

Künstliche Intelligenz für die Hochwasserwarnung (KIWA) | Artificial intelligence for flood warning (KIWA)

Jens Grundmann, Niels Schütze, Anette Eltner, Ralf Hedel, Tanja Morgenstern,
Xabier Blanch, André Kutscher

Download Poster