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Implementing innovations in disaster management to increase resilience – laws, policies, and organizational determinants

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Declaration

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Abstract

Promising innovations offer the possibility to enhance the resilience of a society by improving disaster management processes. However, if and to what extent these opportunities are taken depends significantly on pertinent laws, policies, and organizational factors. Focusing on disaster management in the EU, this thesis thus sought answers to the question: "Which laws, policies, and organizational determinants hinder or support a successful implementation of innovations in disaster management to increase resilience in the EU, and how?" The topic is located at an intersection of research fields including innovation management, resilience, disaster management, security policy, and technology assessment. First, a comprehensive literature-based analysis was conducted to analyze factors that influence the implementation of innovations, both in the private and the public sector, which had been identified in previous studies. Transferring these results to the disaster management domain by considering its specific characteristics led to a first set of innovation determinants. Then, in-depth expert interviews were conducted related to specific cases, i.e., innovations, that have recently been implemented in disaster management. These example innovations stem from Germany, the Netherlands, and Austria (not claiming to be representative for these countries, but allowing conclusions to be drawn related to the EU disaster management system including its market conditions), and cover different types of innovation, such as product innovation vs. organizational innovation, or incremental innovation vs. radical innovation. The experts, i.e., users as well as suppliers of the example innovations, were all intensely involved in the implementation processes and thus have pertinent insights into factors that significantly influenced the implementation of the respective innovations. Finally, consolidating and evaluating the results of the literature-based analysis and the expert interviews led to a new, adapted set of determinants. Identified determinants in the field of laws and policies belong to the thematic groups of "Information sharing", "Cooperation & knowledge sharing", "Protection of employees & of the organization", and "External incentives". Organizational determinants can be categorized by "Staff and work process", "Intra- and interorganizational cooperation", "Innovation culture", and "Compatibility of innovation-specific characteristics". The expert interviews reveal that especially the *Commitment of individuals, Available financial resources,* and *Time* given to implement an innovation extensively determine the success of an innovation implementation. By unravelling innovation determinants in disaster management, the results of the study offer opportunities to support current international approaches to make innovative technology available for disaster response, to reduce the gap between research and market, to enhance disaster management capabilities, and to increase resilience.

Zusammenfassung

Mit vielversprechenden Innovationen bieten sich Chancen, durch ein verbessertes Katastrophenmanagement gesellschaftliche Resilienz zu stärken. Ob und inwiefern diese Chancen genutzt werden hängt ganz wesentlich von Gesetzen, Richtlinien und organisatorischen Faktoren ab. Mit einem Fokus auf Katastrophenmanagement in der EU hat die Dissertation deshalb Antworten auf die Frage "Welche Gesetze, Richtlinien und organisatorischen Faktoren erschweren oder unterstützen eine erfolgreiche Implementierung von Innovationen im Katastrophenmanagement, um die Resilienz in der EU zu stärken; und wie?" gesucht. Das Thema ist in einer Schnittmenge von Forschungsfeldern angesiedelt, darunter Innovationsmanagement, Resilienz, Katastrophenmanagement, Sicherheitspolitik und Technikfolgenabschätzung. Zunächst wurde eine umfangreiche literaturbasierte Analyse durchgeführt, um Einflussfaktoren auf Innovationsimplementierungen sowohl im privaten als auch im öffentlichen Sektor zu analysieren, die bereits in früheren Studien identifiziert worden sind. Diese Ergebnisse wurden dann auf den Bereich des Katastrophenmanagements übertragen, unter Berücksichtigung seiner spezifischen Eigenschaften. Dadurch ergab sich ein erstes Set an Innovationsdeterminanten. Anschließend wurden ausführliche Experteninterviews durchgeführt, bzgl. ausgewählter Innovationen, die kürzlich im Katastrophenmanagement implementiert worden sind. Die Innovationsbeispiele stammen aus Deutschland, den Niederlanden und Österreich (wobei kein Anspruch auf Repräsentativität besteht, aber Rückschlüsse auf Zusammenhänge mit dem EU-Katastrophenmanagementsystem und seinen Marktbedingungen möglich sind) und umfassen verschiedene Innovationstypen wie Produktinnovation vs. Organisationsinnovation, oder inkrementelle Innovation vs. radikale Innovation. Die Experten, Anwender sowie Anbieter der Innovationsbeispiele, waren alle intensiv an den Innovationsimplementierungsprozessen beteiligt, und verfügen daher über einschlägige Erfahrungen im Hinblick auf Faktoren, die einen bedeutenden Einfluss auf die Implementierung hatten. Die Konsolidierung und Auswertung der literaturbasierten Analyse und der Interviewergebnisse ergab schließlich ein neues, angepasstes Set an Innovationsdeterminanten. Im Bereich Gesetze und Richtlinien wurden Determinanten identifiziert, die sich den thematischen Gruppen „Gemeinsame Datennutzung", „Kooperation & Wissensaustausch", „Schutz von Mitarbeitern & der Organisation" sowie „Externe Anreize" zuordnen lassen. Organisatorische Determinanten wurden kategorisiert nach „Mitarbeiter und Arbeitsprozesse", „Intra- und interorganisatorische Zusammenarbeit", „Innovationskultur" und „Kompatibilität innovationsspezifischer Eigenschaften". Die Experteninterviews zeigen, dass insbesondere *Individuelles Engagement*, *Verfügbare finanzielle Ressourcen* und *Zeit*, die für die Implementierung einer Innovation zur Verfügung steht, wesentlich den Erfolg einer Innovationsimplementierung bestimmen. Durch die Analyse von Innovationsdeterminanten im Katastrophenmanagement können die Ergebnisse der Arbeit aktuelle internationale Ansätze unterstützen, um innovative Technologien für die Katastrophenbewältigung verfügbar zu machen, die Kluft zwischen Forschung und Markt zu verringern, Fähigkeiten im Katastrophenmanagement zu stärken und Resilienz zu erhöhen.

Contents

List of Figures

List of Tables

List of abbreviations

CM	Crisis management
CPM	Civil Protection Mechanism
CRED	Centre for Research on the Epidemiology of Disasters
DM	Disaster management
DRM	Disaster risk management
EC	European Commission
EU	European Union
GDPR	General Data Protection Regulation
IPCC	Intergovernmental Panel on Climate Change
IPR	Intellectual property rights
IRGC	International Risk Governance Center
LPO	Laws, policies, and organizational (factors/determinants)
OECD	Organisation for Economic Co-operation and Development
R&D	Research & Development
R&I	Research & Innovation
UNDRR	United Nations Office for Disaster Risk Reduction *(formerly UNISDR)*
UNISDR	United Nations International Strategy for Disaster Reduction

1 Introduction

1.1 Background

1.1.1 Changing challenges

Natural and man-made hazards are changing in terms of type, frequency and intensity. Climate- and weather-related events are clear examples of these changes in frequency and severity (IPCC 2014). Disaster risk is directly affected by both changes in the frequency and intensity of natural hazards as well as by changes in (patterns of) exposure and vulnerability, while populations and assets at risk have increased (IPCC 2012). The earthquake in Haiti 2010, the earthquake/tsunami and nuclear crisis in Japan 2011, the typhoon in the Philippines 2013, or the floods in Europe 2013 are examples where hazards transformed into large-scale disasters. According to a report by the Centre for Research on the Epidemiology of Disasters (CRED) and the United Nations Office for Disaster Risk Reduction (UNDRR), disasters related to natural hazards between 1998 and 2017 have caused 1.3 million deaths. In addition, 4.4 billion have been injured or affected in other ways such as by becoming homeless, being displaced or needing emergency assistance. Economic losses have been valued at US$ 2,908 billion, which is an increase of 68% as compared to the previous 20 year period (Wallemacq and House 2018). While capacities have been enhanced, and risk of mortality due to such large-scale disasters has decreased in countries with higher economic growth, it is still high in less developed countries. Also, even though risk of mortality has decreased, the risk of economic losses has increased in successful economies, accompanied by a growth in exposure (UNISDR 2013; Neumayer and Barthel 2011). The current (2020) worldwide pandemic crisis, which continues to cause a huge number of deaths and enormous economic losses, painfully demonstrates the risk of unexpected crises. Many of the future impacts related to changes in frequency and intensity of hazards are unforeseeable, and several simultaneous changes are interlinked, such as those related to land, ecosystems, energy, industrial and urban systems (UNDRR 2019a).

New technological and other solutions show great promise for optimizing processes including those in disaster management. However, these promises “need to be balanced against the potential evils that the opening of Pandora’s box may entail” (Renn 2014, p. 129). Finding this balance is nontrivial, due to the extent of uncertainties that come with new developments (ibid.). In this context, “emerging” and “systemic” risks deserve special mention. An “emerging” risk is a risk that is new, or at least the conditions in which it appears are new (IRGC 2010). An important characteristic of emerging risks is that it seems impossible to develop confident risk management strategies, because knowledge about these risks and experience with respective events are missing (see e.g. Renn 2014). This is, for example, demonstrated in the current pandemic crisis, since characteristics of the disease are still widely unknown, and respective experience in managing such a crisis is missing. “Systemic” risks as opposed to other types of risk are characterized by their totality, i.e. the probability that an

entire system can collapse (Renn 2016). An increased interconnectedness of systems poses new challenges, such as the ability for risks to transmit faster and further (e.g. disease, terrorism). It also becomes more difficult to address risks that are governed by different organizations or governments (e.g. cross-border or global risks) (OECD 2010). Systemic risks are hence also recognized in the Sendai Framework for Disaster Risk Reduction (UNISDR 2015).

Thus, hazards, their variances and broad range of possible impacts constantly induce new challenges that must be met by continuous improvements and adaptations of the system concerned. Social, political, or technological developments can also require and/or enable changes. Ideally, a system is able to cope with complex disasters in ever more complex societies in the best possible way at any time.

In this context, the term "resilience" has gained lots of attention and triggered large numbers of definitions, concepts, discussions, dedicated research projects, and publications (see e.g. Vollmer et al. 2016; Vollmer and Walther 2018). One definition that is often used is the one from UNISDR: "The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions" (UNISDR 2009).[1] While this study does not foster any principal discussions on resilience, some key aspects of resilience are mentioned, for defining the context of the study.

The term resilience is used in different disciplines – amongst others, ecology, psychology, social research and sustainable science. Alexander (2013) examines the term, its development over historical time, its meaning and uses in an "etymological journey". Alexander concludes that "the modern conception of resilience derives benefit from a rich history of meanings and applications, but that it is dangerous – or at least disappointing – to read too much into the term as a model and a paradigm" (Alexander 2013). Resilience in the context of disaster risk reduction has been focused on in many studies, for instance, Turnbull et al. (2013), who developed guidelines for staff in development and humanitarian organizations, or Egli (2013), who elaborates on "the need for transformational and innovative thinking on preparedness, response, and resilience, as well as disaster management", and states, amongst other things, that resilience should be integrated in all elements, instead of just in protecting physical assets. Due to this development, reviews on the variety of definitions, concepts, and publications on resilience have also been conducted (e.g. Hosseini et al. 2016; Meerow et al. 2016; Vollmer et al. 2016). There seems to be broad agreement on the main attributes of resilience, such as the ability to prepare, absorb, and recover from impacts of a threat. However, different understandings exist, for example, regarding the question of whether resilience means to be

[1] An update of this definition of resilience reads as follows: "The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management", https://www.undrr.org/terminology/resilience (checked on 09/10/2020).

able to "bounce-back" to the previous state, or to learn from the event and adapt accordingly. Or, if resilience means to consider only known, or also unknown threats. Boundaries to related concepts such as vulnerability or risk management are also understood in different ways (Vollmer and Walther 2018).

For the study at hand, an accurate definition with clear boundaries is not crucial. However, it is important to understand the relationship between disaster management and resilience. The study follows the assumption that improvements in disaster management strengthen the resilience of a society as a whole. Resilience thereby *builds on* disaster management, while disaster management is understood as the "organization, planning and application of measures preparing for, responding to and recovering from disasters" (United Nations 2016). It is often used in parallel with emergency or crisis management (see subchapter 1.4). Thus, a high level of resilience requires well-functioning disaster management capacities, while well-functioning disaster management is not always sufficient to achieve a high level of resilience because other resilience aspects might be lacking. However, any enhancement in disaster management capacities means a rise in the resilience level of the affected society. Such an enhancement can be targeted by introducing promising innovations.

1.1.2 Innovations in disaster management to increase resilience

Innovations, i.e. new technical and non-technical solutions[2], can be both new in the sense that a solution itself represents a novel idea, but also new in the sense that a solution is only new within the field of disaster management. Innovations play a crucial role for enhancing disaster management and thus resilience, providing strong opportunities for improving disaster management capabilities, their adaptivity and their performances. These potentials are however often not realized. The widespread use of digitization in everyday life, for example, is not reflected in the field of disaster management, even though data and information management is of vital importance in disaster management (Rainer et al. 2019). The importance of science and technology is also strongly emphasized in the Sendai Framework for Disaster Risk Reduction, significantly stronger than was the case in its predecessor, the Hyogo Framework for Action. However, respective measures remain insufficient (Izumi et al. 2019).

A successful implementation of innovations in disaster management (operational up-take), whether they strengthen resilience, as opposed to triggering negative secondary impacts or providing no real added-value, depends on a variety of factors. These factors include obvious ones such as technical requirements, or the compatibility with other existing solutions, technical or non-technical. But there are also manifold kinds of non-technical context factors potentially preventing successful implementation of new solutions. Basher (2013), for example, finds that barriers to accept, take up and apply technology in disaster risk reduction

[2] "A solution is either one or more processes or one or more tools with related procedures", as defined by the EU project DRIVER+ (Driving Innovation in Crisis Management for European Resilience, 2014-2020), https://www.driver-project.eu/driver-project/terminology/ (checked on 25/04/2019)

are seen in a lack of political interest, inadequate institutional mechanisms, and shortcomings in knowledge availability, technical capacity, standardization and funding. Institutional barriers to implement new technical solutions can be caused by competition and a lack of communication between sectors or departments (Basher 2013). Shortcomings in knowledge availability or expertise are especially relevant factors when non-experts have to deal with difficult technical information, for example probabilistic forecasts of hazard events. Thus, teaching and learning plays a crucial role in bridging the gap between expert and practitioner. Besides this, factors such as world views, risk perceptions, or social structures also play an important role that needs to be considered in the question of if/how new solutions can successfully be transferred into usable techniques (ibid.). However, this only superficially describes relevant determinants on a generic level and does not cover the whole spectrum. This study strives to detail the most relevant context factors ("determinants") that determine successful implementation of innovations in disaster management.

In order to address the most relevant innovation determinants in disaster management, thematic fields, i.e. categories need to be identified in a first step. However, categorizing innovation determinants is not trivial. Many studies deal with this topic, conducted by experts with different backgrounds and from different points of view, resulting in different types of concepts or categories of innovation determinants. A review of a large number of studies on innovation determinants by Souitaris (2003) shows that there is no common view on relevant variables or their actual impact on innovation. While often the same or similar factors are addressed, their influence is assessed differently. In a few cases, there is even disagreement about the direction of influence, i.e., if a factor is correlated positively or negatively. One example is the size of an organization (Crossan and Apaydin 2010; Souitaris 2003). Reasons for these inconsistencies are seen in differences regarding

(1) The nature of innovation (e.g. simple vs. complex innovation); definition of innovation (e.g. what degree of change is required), and measurements of innovation (e.g. selection by industrial experts vs. innovation rate measured through number of new products);
(2) Measurements of the determinants of innovation (e.g. quantitative vs. qualitative variables);
(3) Phases of innovation addressed (factors can e.g. have different effects on the initiation of an innovation than on the implementation of an innovation);
(4) Types of organizations in focus;
(5) Geographical regions (Souitaris 2003).

Despite the differences, Souitaris states that most of the studies result in determinants that cluster around themes, and comes up with a model of potential determinants including the groups

- Contextual variables;
- Strategic variables;

- External communications; and
- Organizational competencies (Souitaris 2003).

In addition to the reasons for different categories of innovation determinants, considering a government-driven market such as the disaster management market leads to a different focus than when considering a consumer driven market, dominated by the private sector.

Based on these considerations, and supported by the results of an analysis of studies on innovation determinants in the private and in the public sector (see subchapters 4.2.1 and 4.2.2), the following groups of innovation determinants in the government-driven market of disaster management are identified (see Figure 1):

- **Technical functionality:** A basic pre-condition for successful innovation is its functionality. It has to suit the purpose. However, technical (dis)functionality is in most cases not identified as a main hurdle. It seems that the implementation of an innovation is not even considered if its functionality is not clearly given. For information sharing and interoperability in emergency response, for example, Allen et al. (2014) find that technology is not a barrier. Instead, organizational and procedural factors are seen as the determining ones. However, it is crucial that a solution functions both in daily work as well as in disaster events (e.g., Allen et al. 2014), and that the technology is not too complex, i.e., that the solution is easy to use (e.g., Weidinger et al. 2018). Hence, technical functionality is not covered as an own group of determinants in this study, however, specific issues related to the compatibility of the technical functionality with organizational pre-conditions are covered within the group of organizational determinants.
- **Laws:** There are different types of legal acts that differ in how binding they are. For example, on EU level, "regulations" have to be applied in their entirety across the EU, while "directives" define a goal that EU countries must achieve.[3] Findings of studies on the relationship between (EU) regulation and innovation include that regulations can strongly stimulate innovation – but also disable innovation. Regulations can either have a general impact, or only in certain sectors, or just related to specific innovations (Blind 2016; Pelkmans and Renda 2014). Due to safety and security requirements, the disaster management market is more strongly regulated than other markets.
- **Policies** can be closely related to legal acts – but also to organizational factors. They encompass governmental issues, consideration of resilience in official strategies, programs, or guidelines; or available budgets for resilience and similar approaches. In addition, the share of power, responsibilities, and chains of command are included here.
- **Organizational factors** that can hinder or support successful innovation concern the structures and characteristics of organizations, e.g. the system of roles and

[3] See https://europa.eu/european-union/eu-law/legal-acts_en (checked on 23/01/2020)

competences within an organization, vertically and horizontally. Factors such as available capabilities, tools, resources, knowledge, regular training, etc. are included, too. They potentially play a specific role in the field of disaster management, due to the public nature of most organizations involved.

- **Societal factors** include aspects such as societal perceptions or expectations regarding the work of disaster management organizations, or regarding support and information offered by organizations. Considering societal aspects is crucial in markets where the population is the main consumer. Also, in the wider field of security, societal factors are of utmost importance in many cases, since applying measures such as surveillance cameras or airport scanners will only work if they are largely accepted by the population. Societal factors in the context of this study appear only relevant in specific cases of innovations that are of strong public interest, e.g., an innovation based on organizational changes within a disaster management organization, or a new building allowing closer collaboration of different organizations is unlikely to cause stronger public concerns. If an innovation is expected to potentially raise public interest and/or concerns, proper information and communication is surely crucial. Societal factors in this study are included indirectly, especially in the categories of laws, and policies. For example, data protection regulations can be seen as a result of societal demands and expectations. Literature on innovation determinants often does not directly include societal factors (e.g., OECD 2017; Vries et al. 2016; Vries et al. 2018; Blind et al. 2012). Hadjimanolis (2003) includes societal factors under the category "Other".

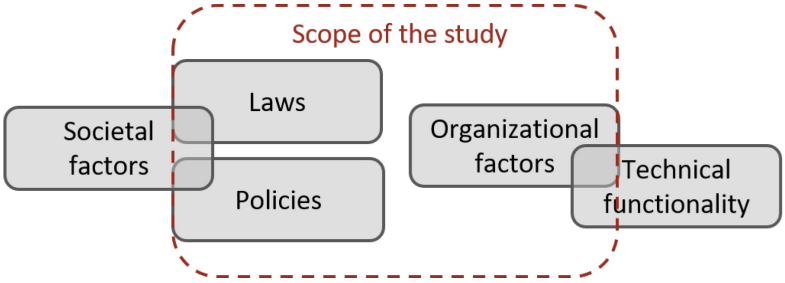

Figure 1: Groups of determinants and their role in the study

1.1.3 Laws, policies, and organizational factors affecting innovation activities

Laws, policies, and organizational (LPO) factors can have different effects on innovation activities. Whether or not LPO factors target innovation, they can directly support innovation, indirectly lead to innovation, hinder innovation, or have no influence at all on innovation (see Figure 2).

LPO factors that directly target innovation are, for example, intellectual property rights (e.g., patents) (Blind 2016). General laws or policies that support innovation in specific fields, e.g., to increase resilience, also belong to this category. Organizational factors in this sense are seen in actions or guidelines of an organization that support a good innovation culture, e.g., by

providing respective incentives. These LPO factors thus usually directly support innovation actions.

The majority of LPO factors however does not address innovation as a first priority ("other objective"). Depending on their nature and the system in focus, they can lead to innovation, hinder innovation, or have no effect on innovation activities. In many cases, LPO factors partly lead to or support innovation, and partly hinder innovation. LPO factors that lead to innovation can be distinguished between those that "push" innovation, and those with an innovation "pull" effect. "Push" refers to LPO factors that require innovation, such as respective laws. New critical infrastructure protection legislation can, for example, oblige stakeholders to take actions that cannot be served by currently used technology/solutions. "Pull" refers to LPO factors that create new demands, which can then lead to innovation. An example from another field is the increased demand for outside heaters following the non-smoking-rule in several federal states in Germany (Männer et al. 2012).

LPO factors that hamper an envisaged innovation are manifold. A well-known example is data protection regulation, which especially comes into play when considering IT or mobile app-related innovations. The collection and use of personal data require respective measures that assure the security of data before the innovative idea can be realized.

As mentioned above, LPO factors can affect innovation in different ways simultaneously, i.e., partly support, and partly hinder innovation. "The net impact of regulation on innovation depends on the extent of the compliance cost on the one hand and the incentive effect on the other hand" (Blind 2016, p. 453). Further, legal acts that require measures, i.e., "push" innovation, can at the same time be seen as "supporting" innovation activities.

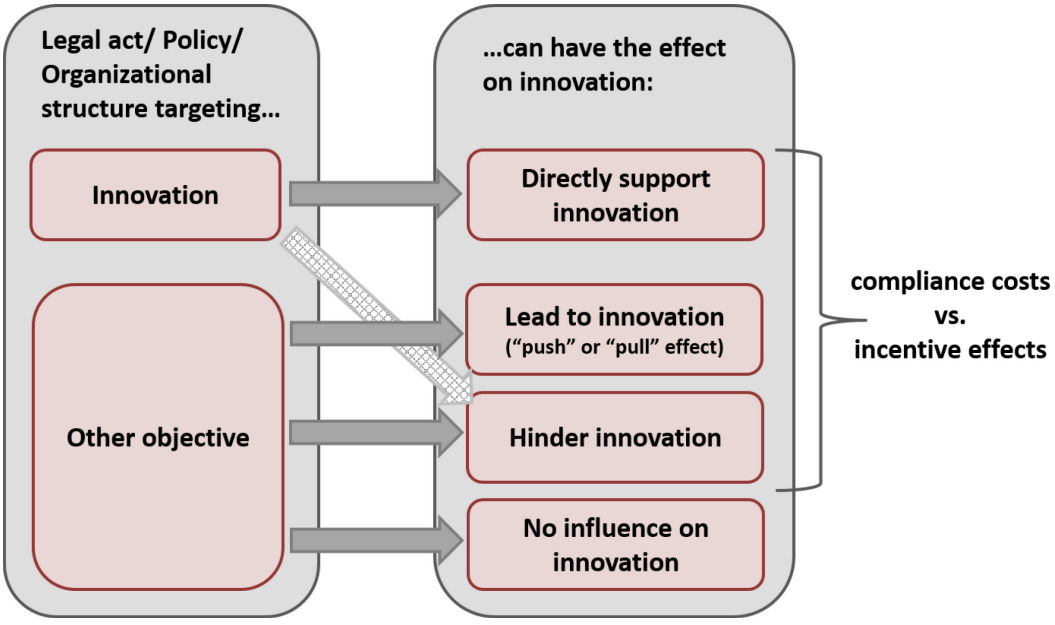

Figure 2: Possible effects of LPO factors on innovation activities

These different possible effects, focusing on innovation implementations in disaster management, are addressed in the present study.

1.2 Related previous research

The topic of this study combines the research field of disaster management, which in itself is an interdisciplinary task, and the research field of innovation management. In addition, a special focus is on laws, policies, and organizational factors. This leads to relations to various disciplines and thus to a broad field of research that is linked to this work (see Figure 3). This subchapter aims to provide an overview of these research fields and how they relate to each other. Results of an in-depth literature-based analysis will follow in chapter 4.

Innovation in disaster management is related to risk management and risk governance. Many studies have discussed the factors of good risk management and risk governance, for example those by van Asselt and Renn (2011), Hutter (2005), Aven (2011), Rosa et al. (2014), or Hood et al. (2004). Aven and Renn (2018) find that, in general, there is agreement about the main principles of risk governance such as openness and transparency, involvement, proportionality and consistency, and making decisions based on evidence. However, they note that existing principles for good risk governance are, in practical situations, often not easily implemented. Moreover, the principles can even contradict each other. Also, finding the best balance between the goals of risk management and the most practically suitable decision options is not trivial (Aven and Renn 2018). Another balance that is sought is the one between efficiency and resilience, in order to achieve economical solutions to minimize negative effects (Renn 2016).

In an OECD publication that aims to identify areas of risk governance to be improved, the legal, procedural and practical challenges for risk regulation have been analyzed (OECD 2010). It refers to organizational structures that have been identified for effective risk management in a review of the approach of the US Federal Aviation Administration to Safety (Independent Review Team 2008). These organizational structures include, amongst others, the ability to identify hazards early in their life cycle, a willingness to engage in searching for appropriate solutions, and an organizational "fluidity" to report risks to the appropriate level in the organization (ibid.). While there seem to be relationships between organizational preconditions for effective risk management and organizational preconditions for effective innovation implementations, they are not the same. For example, the ability of an organization to identify hazards might be – but is not necessarily – related to its ability to identify promising solutions.

Within the research area of technology assessment *(Technikfolgenabschätzung)*, technological trends and related societal developments are analyzed, and respective chances and risks are evaluated. The objective is to identify possible positive and negative impacts at an early stage, to enable appropriate measures to be taken. For example, Grunwald (2010; 2018) and Decker et al. (2012) explain the possible benefits of technology assessment, considering developments such as rapid digitization or nanotechnology, their positive effects but also possible negative

side effects. The German parliament also receives advice from a specialist institution on technology assessment *(Büro für Technikfolgen-Abschätzung beim Deutschen Bundestag (TAB))* (see e.g. Grunwald et al. 2012). Giesecke (2003) as well as Smits and Hertog (2007), for example, also highlight the importance of societal, cultural, and ethical questions regarding possible unintended effects of technological trends.

Intensive research specifically considering the cultural and social aspects of disaster management has been conducted at the Disaster Research Unit of the Freie Universität Berlin (until 2011: Kiel University). This includes an analysis of societal requirements for disaster management by Dombrowsky (2014); the development of a protection data atlas *(Schutzdatenatlas)* (Dombrowsky et al. 2003); a discussion on resilience from a perspective of disaster sociology (Voss and Dittmer 2016); or a sociological conception of disaster combined with theories of communication (Voss and Lorenz 2016).

Disasters do not stop at national borders, and in many cases, more than one country is affected. Or, resources and capabilities of an affected country are exceeded, and external support is required. For cross-border or cross-organizational cooperation (but also joint R&D or procurement) the challenge of harmonization and standardization is an issue of specific relevance in this context. This notably concerns the sometimes very specific not only national, but also local needs in disaster management. In the EU project ACRIMAS[4], for example, "harmonization of language and technology" has been identified as a need for improvement of high priority in EU crisis management. In this context an important problem is seen in institutional barriers (organizational factors) due to the diversified crisis management landscape, where the police, fire brigade, UN, military, various NGOs as well as local organizations are involved (Stolk et al. 2012). Harmonization can take place at the overall organizational level, concerning working methods and procedures, as well as in very specific areas, e.g., in the standardization of technical tools. In both cases, harmonization and/or standardization can have essential influence on the diffusion (or non-diffusion) of solutions. It can also be seen as a specific measure to increase resilience, being requested in laws, or policies/guidelines etc. At the same time, it supports – or hinders – the diffusion or implementation of specific tools.

The role of governance and institutional arrangements in the context of resilience was investigated by Chang Seng (2010 and 2013). Systems of governance and their architecture, regarding their influence on tsunami risk resilience in Indonesia, were investigated. A comprehensive integrated framework was developed and employed to structure the inquiry, and to analyze governance and institutions. Hindering and driving factors for institutional change in disaster risk management were described. For the case study, it was found that the developing polycentric and multi-layered institutions and structures synchronized according

[4] Aftermath Crisis Management System-of-Systems Demonstration, Phase I (2011-2012), https://cordis.europa.eu/project/id/261669/de (checked on 09/10/2020)

to the decentralized political-administrative system are ideal governance architectures for building resilience in Indonesia (Chang Seng 2010; Chang Seng 2013).

Many authors deal with innovation management, for example Burr (2017), addressing economic issues of innovation research; Tidd and Bessant (2014, 2018), providing an approach to managing innovation in different contexts; or Disselkamp (2012), describing requirements for successfully implementing new ideas in companies. Public sector specificities in innovation management have been investigated for example by Bloch and Bugge (2013). Naranjo-Gil (2009) analyzed factors influencing innovation adoptions in the public sector, and Blind et al. (2012) conducted a study on innovation management in public services in Germany and Europe.

An overview of requirements for the application of technology in disaster risk reduction is given by Basher (2013), commissioned by the UNISDR. While some organizational-institutional barriers such as competition between different organizations, lack of communication or lack of knowledge have been mentioned, they are not examined in depth.

A joint initiative of the International Federation of Red Cross and Red Crescent Societies (IFRC) and the United Nations Development Programme (UNDP) analyzed the laws and regulation frameworks for disaster risk reduction in several countries. However, the focus of the analysis is on general disaster risk reduction approaches and strategies, and does not directly address innovation or the implementation of solutions in disaster management (UNDP and IFRC 2014).

Studies focusing on laws, policies and organizational (LPO) determinants and related processes, relevant for innovation success in disaster management, are scarce. However, Cabrera-Alvarado et al. (2013) for instance analyzed the legal and policy framework in the context of satellite technology for disaster management. Amongst them are

- Institutional knowledge;
- Appropriate political guidelines to overcome the problem of economic costs of data, facilitating the free flow and use of data;
- National disaster risk reduction guidelines;
- Privacy and national security, which is subjective to the cultural values and geopolitical climate in a state. Widespread legal uniformity is absent, and a lack of applicable national law on issues of privacy may create legal uncertainty. Thus, acquiring data can prove problematic.
- Intellectual property: ownership of (space-based) intellectual property is not always clear and easy to trace anymore.
- Liability: liability for the accuracy of data can result in a reluctance of parties to share data internationally. Inadequate information and/or delayed availability of data runs the risk of hindering relief efforts when relied upon.
- Licensing: there is legal uncertainty regarding the use and dissemination of data;

- Harmonization of data: standardization of (geospatial) data is missing (Cabrera-Alvarado et al. 2013).

Yun et al. (2011) investigated the development and diffusion of innovations for disaster management using case studies in telecommunications in South Korea. One example is a technology that has been originally developed for mobile broadcasting, which was then used as an optimum solution for efficient delivery of information related to disasters. It thus serves as an example for solutions that have been established in the private sector and are subsequently extended for use in disaster management.

Figure 3 presents the main related fields of research as described in this subchapter. Results of an in-depth literature-based analysis will follow in chapter 4. Literature exists that addresses one of the three main fields, or two of them (intersection of two circles). The thesis' topic is located at the intersection of all three, where barely any other existing literature can be found. So far, even though specific topics have been addressed, there seems to have been no comprehensive analysis of LPO innovation determinants in disaster management.

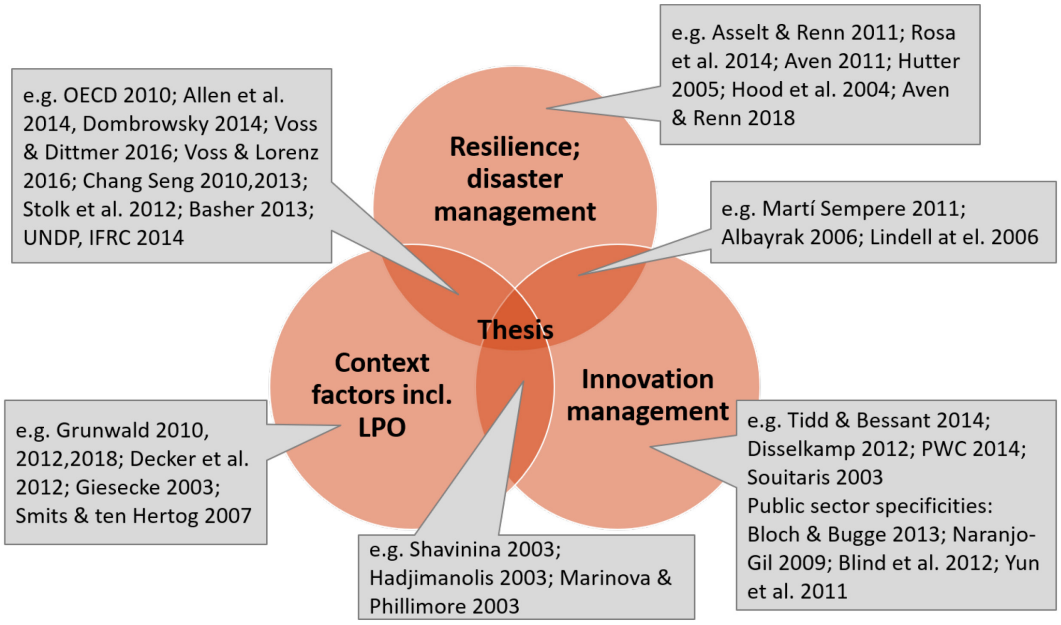

Figure 3: Related research fields

1.3 Research question and objectives

The thesis investigates determinants, i.e., factors that essentially influence (hinder or support) an implementation of innovations in disaster management in order to increase resilience. It examines what hinders or supports disaster management organizations to make progress, to adopt innovations that promise to optimize or at least improve actions in disaster management which would strengthen the resilience of a society. Innovations can be "new" in different ways: They can be of completely novel type, specifically developed to enhance disaster management

practices. They can also be innovations already established in other fields, which also seem useful for adoption for disaster management purposes. But they can also be new just for a specific organization, while already being in regular use by other disaster management organizations.

The factors in focus belong to the groups of LPO determinants, see subchapter 1.1.2. Their relevance can differ greatly depending on the innovation of interest; but their shapes, values or characteristics can also differ greatly, e.g., between different countries, but even different organizations. This is of specific interest if a solution successfully implemented in one region or organization is to be implemented in another region or organization.

As elaborated above, research has so far been missing on the specific role of different LPO determinants for the enhancement of disaster management processes by enabling organizations to use innovations, or in other words, enabling their ability to take on new solutions.

Against this background, the objective of the thesis is to identify and explain relevant LPO determinants with regard to their influence on the implementation of innovations to enhance disaster management, and thereby to increase the resilience of a society.

This objective will be achieved by answering the following research question and its "sub questions":

Which LPO determinants hinder or support a successful implementation of innovations in disaster management to increase resilience in the EU, and how?

Sub-questions:

- *Which LPO determinants can be identified based on previous studies, and how can their influence be described? How can the identified LPO determinants be categorized?*
- *Which LPO determinants can be identified by analyzing recent implementations of innovations in disaster management to increase resilience in the EU (using expert interviews)? In how far does this correspond to results obtained by literature-based analysis?*
- *Which of the identified LPO determinants are innovation specific, and which ones can be transferred to other innovations in disaster management? How?*
- *What are the similarities and differences regarding different types of innovation?*

While the first sub-question can be answered in a comprehensive manner, without focusing on a specific country or region, answering the other sub-questions requires selected examples of innovation implementations in the EU. This allows conclusions to be drawn relative to characteristics of the EU disaster management system and approaches to increase resilience.

Innovations can be of different nature, technical and non-technical. It should be noted that the innovation of interest can also be a law, policy, or an organizational process, so that the difference between the innovation itself and LPO determinants supporting or hindering an innovation implementation is not always clear.

1.4 Terminology

In this subchapter, terms that are relevant for the thesis are defined. While "resilience", "legal acts", "policies", and "organizational determinants" have already been explained in subchapter 1.1.2., it is explained in the following how the terms

- Innovation;
- Innovation determinant;
- Disaster management, emergency management; and
- Disaster risk management

are understood in the thesis.

Innovation

As also noted by Vries et al. (2018), many definitions of innovation used in literature are based on the definition by Rogers (2003): "An innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (Rogers 2003, p. 12). The OECD provides the general definition: "An innovation is a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)" (OECD/Eurostat 2018, p. 20). For innovations in the public sector, the OECD has identified three main characteristics:

- **Novelty** – innovations introduce new approaches in a specific context;
- **Implementation** – innovations must be implemented, not just an idea
- **Impact** – innovations aim to result in better public results including efficiency, effectiveness, and user or employee satisfaction (OECD 2017).

However, innovation is not measurable in an objective way, since people can have different opinions about the question of whether something is really novel and deserves to be called an "innovation" (Burr 2017). Different ways of categorizing innovations can help to better describe a specific innovation, and to explain which kinds and/or phases of innovations are focused on in this study (see Table 1):

Two main ways of categorization are according to the content of the innovation, and according to the degree of innovation/of change.

Innovation types by content:

The innovated object can be products or services; the way products or services are created and delivered; the markets; or underlying models (Tidd and Bessant 2014).

Product innovations are material or immaterial achievements, offering new or better possibilities for the user of the product. Product innovations can concern both material goods as well as services (Burr 2017). Transferred to disaster management, the product innovations can be, for example, the use of drones, or new mobile solutions, but also innovative training methods.

Process innovations, in an economic sense, improve the development of a product, i.e., they increase efficiency, reduce costs and/or produce higher quality (e.g. Burr 2017; Granig and Perusch 2012). Since in this study, the focus is on the implementation process of user organizations, rather than the abilities of suppliers, these types of process innovations are not in focus. However, process innovations can also be understood as immaterial product innovations and/or the required new processes in a user organization that enable an implementation of product innovations, which are of course addressed in the study. These types of innovation can also be understood as "organizational/institutional", see below.

Besides product and process innovations, some authors in innovation research distinguish additional types of innovations related to content:

Organizational/institutional innovations aim at improving organizational processes, organizational culture, or decision-making processes. In the private sector, organizational innovations have been defined as "the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations" (OECD/Eurostat 2005, p. 51). In the public sector, for example Vries et al. (2016) distinguish between "administrative" and "technological" process innovations, while the administrative ones focus on "creation of new organizational forms, the introduction of new management methods and techniques and new working methods" (Vries et al. 2016, p. 153). These administrative process innovations correspond to the organizational innovations as understood in this study. They are directly addressed in the study if they concern changes in a disaster management organization. They are further indirectly addressed through the assessment of organizational determinants, and also of policy factors.

Innovation types by degree of innovation/degree of change:
The degree of innovation, i.e., the degree of "being new" ranges from innovations that are *fundamentally new* to innovations that *improve* products or processes, and to innovations that *"imitate"* existing products or services by adapting to the organization's specific needs (Hoffmann-Riem 2016; Granig and Perusch 2012).

The degree of change ranges from *radical (or revolutionary)* innovations that are completely new products or services, to *incremental (or evolutionary)* innovations as small changes to existing products or services (Burr 2017). While this study does not consider "innovations" from the lower end of this range, i.e. small changes such as slightly improved vehicles, the innovations considered do not have to be revolutionary.

Innovation types by reference unit ("new for whom"):
Innovations can further be classified by the reference unit, i.e., for whom the innovation is actually "new". This can be an individual, an organization, a branch, a nation, or on an international level (Granig and Perusch 2012; Hauschildt et al. 2016)

Table 1 provides an overview of the categories of innovation types, and how they are addressed in this study.

Table 1: Categories of innovation types

Innovation type by…		Addressed in the study
…content	Product innovations	Yes
	Process innovations	No (only those understood as organizational/institutional)
	Organizational/institutional innovation	Yes
…degree of innovation	Fundamentally new innovation	Yes
	Innovation improving product/process	Yes
	Innovation imitating existing products	Yes
…degree of change	Radical/revolutionary	Yes
	Incremental/evolutionary	Yes, if more than minimal change
…reference unit	Individual	No
	Organization	Yes
	Branch	Yes
	Nation	Yes
	International	Yes

The different classifications are all related to *change*. Innovation, however, always means change aiming to create value. This value can be of a financial type, but not necessarily – it can also be a social value (Tidd and Bessant 2014). The latter seems relevant in most cases of innovation in disaster management. Innovation activities are usually also a result of competition. This can be competition between companies, but "competing" can also be understood as taking the challenge of limited resources being available for achieving social goals (ibid.), such as enhancing disaster management competences.

It should further be noted that the emphasis in this study is on the *implementation* phase of an innovation, e.g., as compared to generating ideas/concepts or the development of an innovation. This is due to the observation that potentials are often available, i.e. potentially useful solutions exist, but are not sufficiently implemented in disaster management (see subchapter 1.1.2). The study aims at identifying reasons for this observation. However, factors that influence the different innovation phases are closely interlinked, and factors of other innovation phases are not excluded, as long as they also affect the implementation phase.

Another term often used in literature on innovation is *diffusion*. A commonly cited definition is the one by Rogers (2003): "Diffusion is the process in which an innovation is communicated through certain channels over time among the members of a social system" (Rogers 2003, p. 5). It is thus about spreading or disseminating innovations. While the concept of diffusion seems most relevant from a supplier's perspective, the focus of this study is the perspective of disaster management organizations. However, identified factors on the diffusion of innovations can also be relevant regarding the determinants focused on in this study.

Innovation determinant

An innovation determinant as understood in this study is a factor, aspect, or issue that influences ("determines") the implementation of an innovation in disaster management. Thus, the degree, velocity, or success of an innovation implementation depends on these innovation determinants. Their influence can be positive or negative, i.e., supporting or hindering the implementation process. Other terms used in literature are "factor", or "antecedent". Supporting factors are also called "facilitators", and for hindering determinants, amongst others the terms "barrier", "hurdle", or "failure factor" are used. A comprehensive list of terms used for innovation hindering factors is provided by Cinar et al. (2019).

Disaster management/emergency management:

Disaster management and emergency management are terms often used interchangeably. However, according to the UNDRR, disaster management is

"The organization, planning and application of measures preparing for, responding to and recovering from disasters.
Annotation: Disaster management may not completely avert or eliminate the threats; it focuses on creating and implementing preparedness and other plans to decrease the impact of disasters and 'build back better'. Failure to create and apply a plan could lead to damage to life, assets and lost revenue" (United Nations 2016, p. 14).

*"**Emergency management** is also used, sometimes interchangeable, with the term disaster management, particularly in the context of biological and technological hazards and for health emergencies. While there is a large degree of overlap, an emergency can also relate to hazardous events that do not result in the serious disruption of the functioning of a community or society"* (United Nations 2016, p. 14).

The focus of this study is disaster management. Emergency management however is also addressed on several occasions, since many solutions used for an "emergency" are also used for "disasters". Further, while disaster *management* actually refers to the organization and planning part, the innovations as understood in this study are intended to enhance preparing for, responding to, or recovering from disasters.

Disaster risk management

While disaster management focusses on preparation, response and recovery, the term disaster risk management is understood more broadly, and especially encompasses the prevention and reduction of disaster risk. The UNDRR definition is: *"Disaster risk management is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses"* (United Nations 2016, p. 15).

Disaster risk management activities can include, for example, adapted land-use planning, or reducing exposure, e.g., by relocating critical infrastructure assets (ibid.). Such activities require different kinds of solutions than those which enhance preparing for, responding to, or recovering from disasters. Thus, innovations in "disaster management" are addressed in this study which could also serve "disaster risk management", while several other types of solutions in disaster risk management are beyond the focus of this study.

1.5 Structure of the thesis

In order to answer the research questions formulated in subchapter 1.3, the thesis is structured as follows: Considering the thesis' focus on disaster management and resilience in the EU, **chapter 2** introduces its pertinent characteristics. This allows respective conclusions related to the analyzed innovation determinants, e.g. specific market structures (especially in chapters 4, 5 and 6). **Chapter 3** explains the applied methodology (overview in subchapter 3.1): First, a comprehensive literature analysis is conducted to analyze innovation determinants that were identified in previous studies, both for the private and the public sector. Transferring the results to the disaster management domain by considering its specificities leads to a first set of innovation determinants. The methodology of this literature-based analysis is explained in subchapter 3.2, the results are described in **chapter 4**. Then, expert interviews are conducted related to specific cases, i.e., innovations that have recently been implemented in disaster management. The innovation examples stem from Germany, The Netherlands, and Austria, and cover different types of innovation. The respective methodology is explained in subchapter 3.3, the results are described in **chapter 5.** The results of the literature-based analysis (chapter 4) and the expert interviews (chapter 5) are consolidated in **chapter 6**, deriving a new, adapted set of determinants. **Chapter 7** discusses the results, explains how the research questions are answered, reflects the applied methodology, and relates the findings to previous work. Finally, **chapter 8** includes recommendations for further research as well as practical implications, and puts the results in the context of international approaches that address disaster management and resilience.

2 Disaster management in the EU

Since the thesis focusses on disaster management in the EU, this chapter summarizes the general structures of EU disaster management, including an overview of stakeholders and general approaches, as well as relevant market conditions.

2.1 General structures

As explained in subchapter 1.4, disaster management is defined as the *"organization, planning and application of measures preparing for, responding to and recovering from disasters"* (United Nations 2016). In order to understand peculiarities of the EU disaster management structure and its market, it seems useful to gain an understanding of the relevant actors or stakeholders.

Stakeholders in disaster management

Lindell (2006) classifies *social groups, economic groups*, and *political groups* within community stakeholders in the US context (Lindell et al. 2006), which can also be transferred to the European context:

Social groups include households, private sector groups (religious groups, other NGOs), nonprofit organizations, community-based organizations, and businesses.

Economic groups include businesses, while public utility providers (whether privately or publicly owned) are an especially important type. They include providers of electricity, water, sewer services, solid waste management, and communications. In addition, insurance and some real estate developers are involved in disaster management processes. Another type of business with a special role in disaster management is the news media. It is important both for information during a disaster, and training prior to an event.

Political groups involve governmental organizations at different levels (municipality being the lowest level), with different levels of power. At the local level, the agencies most involved in disaster management are the fire and police departments, as well as emergency medical services agencies. On regional/state level, emergency management agencies as well as pertinent academia are participants. At the national level, further organizations are involved, e.g. a national disaster management agency (in the US: FEMA), as well as organizations such as weather services (Lindell et al. 2006).

Considering the possible different incentives for innovation (especially profit vs. social incentives), it seems reasonable to distinguish between governmental, non-profit, and for-profit organizations among the main stakeholders in disaster management, see Table 2.

In this study, public organizations are in focus, which constitute the majority of organizations involved in disaster management. Several non-governmental organizations are likely to have similar incentives to innovate since social welfare is their main goal. Profit organizations are addressed in the study in the sense that their knowledge and expertise is captured (by means of expert interviews) as suppliers of innovations that have been implemented in public disaster management organizations.

Table 2: Main stakeholders in disaster management

Governmental	Non-governmental	
	Non-profit	For-profit
Governmental civil protection organization (e.g. THW)	Individuals, households	Businesses selling disaster management tools and solutions
Public critical infrastructure providers		Private critical infrastructure providers
Fire brigades	Volunteers	
Police		
Emergency medical/first aid services	Emergency medical/first aid services (e.g. Red Cross, The Johanniter)	
Hospitals		
Media		
Education and research organizations		
Municipalities		
National and sub-national (e.g. federal state; county) authorities		
International organizations (e.g. EU, UN)		

In order to put the study into the context of EU disaster management, a short overview of the main approaches and institutions in EU disaster management is provided:

Approaches and institutions in EU disaster management

In addition to bilateral or trilateral agreements on disaster relief between single countries, international assistance is organized on EU level: The main department responsible for disaster management is the Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG ECHO) of the European Commission. DG ECHO is, amongst others, in charge of the EU Civil Protection Mechanism (EU CPM), which was established in 2001 in order to coordinate international assistance from the EU to victims of disaster events. The EU CPM pools capacities from the EU Member States, six participating states, and the UK. Any of these countries can request assistance via the EU CPM when the scale of a disaster overwhelms its own response capabilities. (Any other country in the world as well as UN organizations can also request assistance via the EU CPM.) The request goes to the Emergency Response Coordination Centre (ERCC), which is the operational part of the EU CPM. Other countries then offer assistance, such as personnel, relief items and specialized equipment. Once accepted, the ERCC coordinates the delivery of assistance to the affected country. Through the EU CPM, operational costs (e.g. transport costs) can be co-financed by the European Commission, thus enabling fast delivery of assistance with lower budgetary impact on the countries offering the assistance (European Union/ECHO 2020c, 2020a).

The European Civil Protection Pool (ECPP) was established to improve the coordination of response activities. Countries participating in the EU CPM commit national resources to the pool, such as rescue or medical teams, experts, specialized equipment or transportation. When a request for assistance through the EU CPM is received, assistance is provided by the ECPP. In order to ensure that the resources of the ECPP meet high standards and will function properly when applied in disaster response, a certification process has been set up by the European Commission. When capacities are applied, or need to be repaired or upgraded, the Commission provides financial support (European Union/ECHO 2020d). When all the capacities of participating countries are already in use, the "rescEU reserve" can be used. RescEU was established in 2019 as an additional element of the EU CPM. Its reserve of resources includes firefighting planes and helicopters, medical evacuation planes, as well as a stockpile of medical equipment and field hospitals (European Union/ECHO 2020e). Following the experience of the current pandemic crisis caused by the coronavirus, where several EU Member States were lacking resources and the EU was not able to offer the required equipment, rescEU will be significantly reinforced by an extra budget of €2 billion for the period 2021-2027 (European Union/ECHO 2020b).

2.2 The market of disaster management

Since innovation processes are inextricably connected with the respective market, this subchapter reflects upon characteristics of the disaster management market.

The boundaries of the disaster management sector, like the whole security sector, are rather unclear. One reason is that many products are drawn from other economic sectors, which means that some of the products used for disaster management are actually produced for other sectors, but also that many suppliers for disaster management operate in other sectors as well. For some suppliers, security or disaster management products or services are only a very small part of their business. The boundary to the health sector for example is not clear because several products and services aiming at protecting the population against injuries or illnesses are also necessary for disaster response (see Martí 2011).

According to the "Action Plan for an innovative and competitive Security Industry" of the European Commission (European Commission 2012), the EU security industry faces three main challenges. To a great extent these also apply to the disaster management sector, which is just one part of the broader security sector:

(1) **Fragmentation of the market along national or even regional boundaries:** Countries usually opt to maintain their own regulations, due to the sensitive nature of security. As a result, the EU market is fragmented, and there are higher barriers to entering one country's market. If companies want to address another nation's market, they might be forced to invest more, due to the differing characteristics of that market. This might discourage them from going beyond their own national borders.
(2) **The gap between research and market:** Even though this is a general challenge affecting all sectors, it is specifically true for the security sector. This is because

customers in the security market are mainly public authorities, who often lack information on security technologies. These public authorities are highly diversified, ranging from national to local governments, and different types of organizations such as police, fire brigades, public and private infrastructure providers, etc. In contrast, in the area of defense, there is usually just one customer, i.e., the national ministry of defense. In addition, the market is often driven by disaster events/crises, and security requirements are defined in regulatory frameworks. EU initiatives have been addressing this issue, but the problem still persists.

(3) **Societal/ethical dimension:** Security measures and technologies can trigger the fear of privacy or freedom being violated (European Commission 2012).

The third aspect is certainly true for security measures that directly affect the population, such as surveillance cameras or airport scanners. It is also true for some solutions in disaster management, e.g., if a mobile app is intended to collect personal data. Thus, data protection regulations present an aspect to be considered. However, the main part of innovative solutions addressed in this study only indirectly affects the population, such as organizational changes within a disaster management organization, or an integrated operational control center.

For analyzing innovation implementations in a user's organization, the structure of the disaster management market should be considered, as well as how the characteristics of the disaster management sector influences the demand side. As mentioned above, the main customers in the disaster management sector are public organizations. The government is the main provider of security to society, and roles and responsibilities are distributed across different public organizations, differing in their tasks (e.g. police forces, fire brigades, emergency or civil protection organizations) as well as geographical operational scope (e.g. on local, regional, or national level). Since most of them possess autonomy in purchasing products and services, there is no centralized or coherent procurement pattern (Martí 2011). Decisions of public authorities to purchase products are also determined by risk perception and may be influenced by an attempt to produce positive attitudes among the population, especially in times of upcoming elections (ibid.).

What authorities finally purchase can also be affected by the above-mentioned market fragmentation. There is limited competition among suppliers, which can lead to higher prices and a lack of appropriate products available to users. The market fragmentation is further boosted by a lack of EU-wide standards, so that suppliers cannot be sure about the users' expectations, and hence possibly hesitate to invest in product development. Thus, users possibly buy products that do not entirely fulfill their requirements (European Commission 2012).

Private companies on the demand side in disaster management especially play a role if they are critical infrastructure providers (e.g., transportation, health, energy, water, information and communication, finance, food, chemical sector) (Martí 2011). They are, however, not focused on in this study. Individuals are the smallest market segment in the security sector,

especially involving products and services for ordinary crime and theft prevention (ibid.). It is thus even smaller for disaster management, and not focused on in this study.

In addition to these special market conditions that influence innovation behavior in the disaster management sector, many organizations involved in disaster management possess special characteristics that essentially determine innovation activities as well. They will be described in subchapter 4.2.3.

3 Methodology

In this chapter, the methodology used in the study is explained. Subchapter 3.1 introduces the overall methodology, which consists of two main parts – a literature-based analysis and expert interviews. The literature-based analysis is further explained in subchapter 3.2, the expert interviews in subchapter 3.3.

3.1 Overview

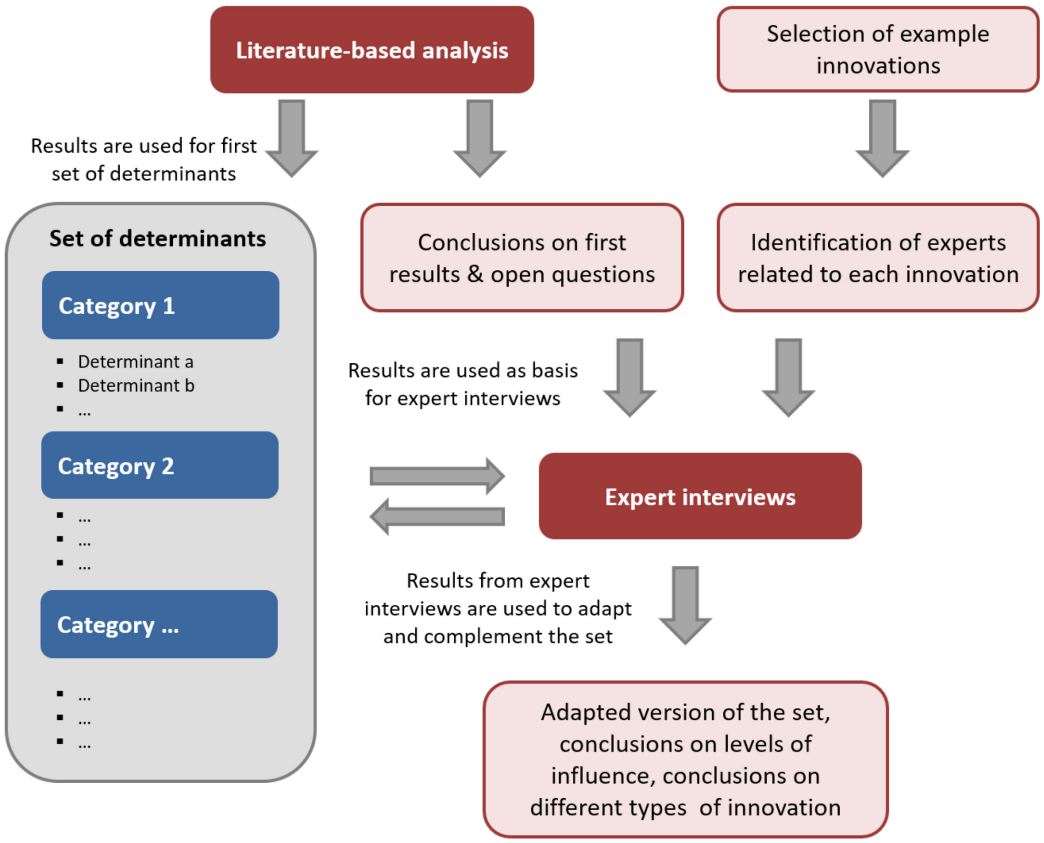

Figure 4: Methodology

Statistical data on innovation implementation processes in disaster management, which could provide answers to the research questions, does not exist. Instead, transferring results of previous studies to the disaster management domain, complemented by gathering the knowledge of experts intensely involved in innovation implementation processes in disaster

management, is expected to reveal underlying factors of innovation implementation processes. Thus, the methodology of this study consists of a literature-based analysis and conducting expert interviews related to a selection of innovations implemented in disaster management. The literature analysis is to lead to the development of a first set of determinants, displaying laws, policies, and organizational (LPO) determinants that influence innovation implementation processes in different categories. The purpose of the expert interviews, each related to a specific example of innovation implementation in disaster management, is to validate or adapt the set, to identify additional aspects, and to answer open questions. "Key messages come from the world of experience. What we've learned comes from the laboratory of practice rather than from some deeply rooted theory" (Tidd and Bessant 2014, p. 13). Based on the results, the set of determinants is then refined. This procedure is displayed in Figure 4.

3.2 Literature-based analysis

3.2.1 Objectives and role in the study

The objective of the literature-based analysis is to derive innovation determinants from existing studies and to transfer these to the field of disaster management while considering the specificities of the disaster management sector. It thus goes beyond a "state of the art" description. It also differs to a literature review that summarizes, aggregates, and organizes previous studies. Instead, the literature-based analysis extracts and evaluates results; innovation determinants identified in previous studies are detected, compared, and analyzed by transferring them to the disaster management domain, considering the context of the study. In addition, the identified and transferred determinants will be adapted in a way that they are all on the same – or at least a similar/comparable – level of abstraction.

While only few studies on innovation determinants in disaster management exist, there are many studies addressing the private sector, and – a little less – addressing the public sector. While mainly studies that specifically analyze innovation determinants are included, also studies with a different focus are analyzed, from which the relevant determinants can be derived.

A first set of innovation determinants will be derived, which, according to existing literature and considering the specificities of the disaster management sector, seem most relevant for the implementation of innovations in the field of disaster management, and to serve as a basis for the expert interviews.

3.2.2 Sources

Disaster management itself is an interdisciplinary task. The field of innovation management adds another topic that has been examined in particular for the private sector. This means, literature from various disciplines has to be assessed and evaluated, such as economics, innovation management, (organizational) resilience, organizational change management, disaster risk management, security, policy and law.

Various databases are searched, such as Web of Science, Science Direct, Google Scholar, and especially e-Lib – a system that searches different databases such as Web of Science, Scopus, Science Direct, SpringerLink, and others simultaneously (available within the Fraunhofer-Gesellschaft). Keywords such as "innovation", "innovation management", "innovation implementation", "barriers", "enablers", "determinants", "factors", "emergency management/response", "disaster management/response", "crisis management/response", in different combinations, are used for the searches. Irrelevant results are sorted out by inspecting the titles and abstracts of the resulting literature. The remaining literature is inspected in more detail; candidate innovation determinants are extracted. In addition, literature cited in key literature is screened, especially in pertinent review articles.

The extracted determinants are checked against specific characteristics of the disaster management sector and selected for the preliminary set of innovation determinants, to be verified, refuted, or adapted through the results of the expert interviews.

Results and the concrete application of the literature-based analysis methodology are presented in chapter 4.

3.3 Expert interviews

The experts are chosen in relation to a selected number of innovations which have recently been implemented in disaster management (see Figure 5). The choice of experts is then based on the degree of involvement in an implementation process. The experts comprise users as well as suppliers of an innovation. While the users should be interviewed in each case, suppliers are not required if they were not directly involved in an implementation process.

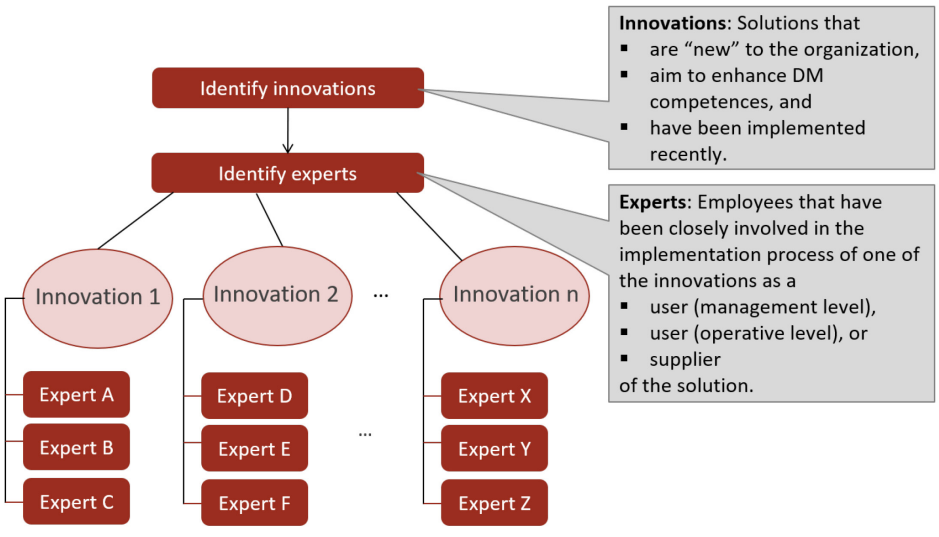

Figure 5: Selection of innovations and experts

After settling the overall objectives of the expert interviews in subchapter 3.3.1, the selection of innovations (subchapter 3.3.2) and of experts (subchapter 3.3.3), both including criteria for selection, is explained. Subchapter 3.3.4 then describes the preparation and execution of the

interviews, and subchapter 3.3.5 encompasses the basic evaluation procedure. Finally, subchapter 3.3.6 depicts the use of the results, including criteria for a quality check.

3.3.1 Objectives and role in the study

The expert interviews in this study serve to validate or refute the results from the literature-based analysis, to identify additional aspects, as well as to answer possible questions that have arisen from the literature analysis. They also serve to develop hypotheses on differences regarding different types of innovation. They play a major role in this study since the topic is not sufficiently covered in the literature.

The ambition is not only to identify factors that have played a role in a specific case, but also to identify "why and how". An interview allows specific questions to be asked subsequent to a narrative part. This can reveal factors that were not at all expected.

3.3.2 Selection of innovations

As outlined above, the expert interviews are conducted relative to selected innovations recently implemented in disaster management. This way, it is possible to identify very concrete factors instead of receiving general statements and impressions. Several possible sources for example innovations are considered; the results will be presented in subchapter 5.1.1. The criteria for selecting examples are explained in the following. How these are met will be explained in subchapter 5.1.2.

The most relevant criteria for the selection of innovations are:

(1) Covering different types of innovation

The main types of innovations (see subchapter 1.4) to be covered concern the content (product innovation and organizational innovation) and the degree of innovation (fundamentally new innovation, innovation improving product/process, and innovation imitating existing products). In this way, different levels of relevance for specific determinants according to different types of innovation can be indicated.

(2) Timeframe of implementation

The analysis using expert interviews follows the approach of illuminating innovation determinants related to real cases of innovation implementations. Using examples of innovations that were implemented a long time ago would imply the risk that either those persons that were involved in the implementation process are not available anymore, or challenge the memory of the respective experts. In addition, more recent implementations are possibly more relevant for upcoming innovations, as the solutions as well as context factors are probably more up to date. Thus, the selected innovations were all implemented within the last few years.

(3) Being "new"

As explained in subchapter 1.4, even small changes to an existing tool or process can be seen as an "innovation". However, the example solutions selected should present a higher degree

of change (while not necessarily radical changes), since determinants will then most likely be more apparent.

(4) Relevance for other organizations
Selecting an innovation that is only relevant for one specific organization could reveal determinants pertinent for this specific implementation process. However, the results will be more significant the higher the relevance is for other organizations, e.g., a tool that could also be useful for other disaster management organizations.

Innovations are selected that have been implemented within the EU, in order to allow conclusions to be drawn related to the EU disaster management system including its market conditions (see chapter 2). The EU encompasses countries with different context factors and national disaster management systems, however, the chosen approach neither targets nor allows a comparison of different countries.

3.3.3 Selection of experts

While for quantitative research methods, representativeness is a key requirement, in qualitative research using expert interviews, the relevance of interviewees is decisive. Before selecting experts for the interviews, it is reasonable to reflect on what an "expert" actually is and which attributes a person should possess in order to be an appropriate expert interview partner for the study.

In common language, an expert is a person with profound knowledge, a connoisseur, or a specialist. An expert interview targets persons with specific knowledge in regard to the research interest (Liebold and Trinczek 2009). In contrast to other forms of open interviews, the interviewed person him/herself in the context of his/her individual life is not the matter of the analysis. It is rather the organizational or institutional context defining a person as an expert. According to Meuser and Nagel (1991), an expert is someone

- who is responsible for the draft, the implementation, or the control of a solution, or
- who possesses privileged access to information on groups of persons or decision processes.

Applied to the context of this study, this means that an expert is someone

- who is, or has been in a responsible position for the implementation of an innovative solution in disaster management, and/or
- who possesses access to information on related regulations, structures, processes, or (groups of) persons.

According to this, the selection of experts should consider who actually possesses the required information about the process that is to be reconstructed. This may mean that several actors with different roles in the process need to be interviewed (Gläser and Laudel 2010).

Meuser and Nagel (1991) explain that it is often not at the highest level within an organization where experts can be found, but rather at a lower level, where decision processes are prepared, and where more detailed knowledge about internal processes is available. For this study, different levels can be relevant – for example a director of a user organization, with insights on management level, and a user on the operational level, for the insights of an actual user of the innovation. Conducting interviews with both levels, plus the provider of a solution can cover the different views and perceptions. It is decided on a case-by-case basis for the different selected innovations, which groups are covered by an expert interview. Further, the required knowledge and experience will mainly be possessed by persons who have experienced the implementation of the innovation from scratch, or at least the main part of it. Thus, only experts from this group are considered.

The selected experts are presented in subchapter 5.1.3 (Table 6).

3.3.4 Preparation and execution

Possible experts, i.e., persons that have been involved in the implementation processes of the selected innovations (see subchapter 3.3.2), are contacted – either directly, or through a first contact who can give advice on an appropriate candidate. Contacting possible experts (or first contact persons) is carried out via email, telephone, or at fairs and conferences. The background, as well as contents, objectives, and estimated duration of the interview are explained. If an expert agrees to participate, the interview guideline (see Annex) and an informed consent form, to be signed by the expert, are provided prior to the interview.

The interviews aim at gaining information on

- The overall implementation process of the innovation;
- The personal experience of the interviewee in the process;
- Factors that had an influence on the way or the velocity of the implementation process;
- Relevance of these factors.

The format of semi-structured interviews (in contrast to, e.g., purely narrative interviews, or interviews following a strict structure) was chosen, because on the one hand, the experts are expected to talk about situations and issues they have been confronted with during the innovation's implementation phase, requiring an interview format that leaves sufficient room for narration. On the other hand, it is likely that during the narration, not all of the determinants, or aspects related to the determinants, as identified in the literature analysis are mentioned and described regarding the specific case from the expert's point of view. Thus, following a narration part, in case specific determinants have not yet been mentioned, they are specifically addressed. Thus, the interview structure is intended to ensure that the expert's view on all relevant aspects is captured. The structure enables both the comparison of different interview results, and the comparison of the interview results with results from the literature-based analysis.

The interview guideline comprises the following questions:

(1) Can you please tell me about *the overall implementation process* of [the example solution] in [your organization]? (starting from the first idea)

(2) Can you please tell me about *your personal experience* with the implementation process?

(3) From your point of view, *which factors had an influence* on the way or the velocity of the implementation? (e.g. regulations, structures, working processes…)

(4) Can you please *elaborate on the different factors* mentioned under 3)?

(Possibly, the interviewer will ask about factors that have not already been mentioned.)

(5) Summarizing the different influencing factors, *how strong* was the influence of each factor, from your point of view?

(6) Where do you see *possibilities to improve* the situation for future innovations?

(7) Is there *anything else* that you would like to mention/that seems relevant from your point of view?

The interviews are recorded and transcribed, with the transcripts accurately reproducing the contents, close to a literal reproduction. Literal quotes are included in cases of very important and significant statements.

3.3.5 Evaluation

There are several ways to evaluate the results of expert interviews; there is not only one single established method (Bogner et al. 2014). The methodology chosen for this study mainly corresponds to the qualitative content analysis methodology by Mayring (see e.g. Mayring 2000, 2014), which has also been the basis for other methodologies developed in recent years (Dresing and Pehl 2018).

This method is characterized by having categories as a focus of the analysis, i.e., text parts are assigned to categories, which then form the basis of further analysis. Categories are used to concretize the research objective and enable results to be compared. They can also contribute to a common understanding and allow others to reconstruct the analysis (Mayring 2014).

This approach seems most suitable for the study's purpose and approach, since the innovation determinants as identified through literature-based analysis already form a first set of categories. A second group of categories is derived from the interviews, corresponding to additional (possibly innovation-specific) innovation determinants. As a third step, some further categories are defined that do not represent any specific determinant, but other aspects that, for example, help to understand the context of the innovation implementation. This procedure also helps to sort out parts of the text material that are not used for further evaluation.

The first two types of categories mentioned correspond to deductive category assignment and inductive category formation as explained by Mayring (e.g. 2000, 2014):

Deductive category assignment
This method uses categories that have been formulated prior to the content analysis. They are theoretically based, derived from considerations on the research topic. The categories should be clearly defined. Then the text is coded, i.e., text sections that belong to a specific category are marked accordingly (Mayring 2014). The deductive categories in the thesis correspond to the determinants as identified and derived from literature.

Inductive category formation
The inductive categories are derived from the text, and have not been defined beforehand. This method "aims at a true description without bias owing to the preconceptions of the researcher, an understanding of the material in terms of the material" (Mayring 2014, p. 79). The categories are not defined beforehand, and the level or theme of the categories needs to be defined to enable new categories to be formulated. Any text section that fulfills this definition is checked to see if a suitable category already exists, or if a new one needs to be created (Mayring 2014).

The interview evaluation process in the thesis, using a combination of deductive and inductive categories, is as follows:

1) Determinants from the literature-based analysis serve as a first set of categories. They are already defined in the literature analysis part (subchapter 4.3).
2) Text sections of the transcribed interviews are assigned to existing categories. If a determinant is addressed that has not yet been defined, a new category and determinant is defined.
3) After coding part of the text (Mayring (2000, 2014) proposes 10-50% of the material), the adapted category system is revised, then the text is checked again.
4) In addition, the level of abstraction is checked, in order to have an appropriate number of categories. As a rule of thumb, Mayring (2014) suggests a set of ten to thirty categories as a useful number.
5) It is also suggested to structure the set of categories by formulating main categories. Such main categories already exist for the determinants also derived from results of the literature analysis. Possible further main categories are added based on the adapted set of categories.

Other approaches also suggest paraphrasing text sections prior to their further analysis (Meuser and Nagel 1991, 2009). This, however, seems not useful in this case, since the determinants (i.e. the categories) are key. "Paraphrasing" only takes place during the explanation and analysis part following collection of all text sections of one category in order not to lose any important information. In addition, the coding part already identifies text

sections that do not require any further analysis, so that paraphrasing these sections would be useless.

The software MAXQDA is used for evaluation, this facilitates a qualitative evaluation of descriptions of determinants. MAXQDA allows categories to be assigned to text passages and the collection of all text passages of one category – while it is possible that a determinant is only addressed in an answer to a question specifically addressing this issue, it is likely that in many cases the topic related to a specific determinant occurs at several stages of the interview. Thus, the function of collecting all text passages assigned to a specific category is very helpful for evaluation. The software can also count the occurrence of categories.

3.3.6 Use of results

In general, qualitative research approaches often follow an inductive way of increasing knowledge, i.e., gathering universal results based on an analysis of individual cases. This is also true for the expert interviews in this study, where it is even more difficult to select "representative" cases, because regularities across solutions and organizations in disaster management are missing. This means that results cannot be handled as proven results beyond the single cases. However, they can confirm or refute hypotheses from the literature-based analysis. Thus, they can indicate if the relevance of determinants as identified in the literature-based analysis is plausible or not, and further explain the character of their influence in particular.

Furthermore, when using quantitative research methods, if a sample is representative, results can be generalized respectively. However, in qualitative research, this must be decided and justified on a case-by-case basis. Thus, it is assessed for each determinant, as to what extent the respective results of the expert interviews can be generalized or transferred to other cases. This is also true for the different innovation types, i.e., differing effects of a determinant depending on the type of innovation (such as product innovation vs. organizational innovation) are examined as well.

In order to ensure the high quality of the evaluation process, the following criteria are assessed, based on Mayring 2014:

- **Semantic validity:** A check is carried out on whether the defined categories are appropriate. All text passages of the transcribed interviews that have been assigned to a specific category are collected. Then, these text passages are assessed regarding homogeneity, and checked against the whole set of defined categories/set of determinants.
- **Sampling validity:** A check is carried out on whether the sampling has been accurate. This corresponds to the selection criteria for innovations and experts as explained in subchapters 3.3.2 and 3.3.3.
- **Correlational validity:** For this criterion, usually the results derived from applying the chosen methodology are compared to results derived from applying other methods. In

this case, apparently the only possibility is to compare the results of the expert interviews to the results of the literature-based analysis – which is an essential part of the study's methodology. Deviations between results of the literature-based analysis and of the expert interviews are carefully assessed and evaluated.

- **Stability – intra-coder agreement:** After finishing the first round of coding, a second round starts, and the results are compared.

The results of applying this methodology will be presented mainly in chapters 4 (results of literature-based analysis), 5 (results of expert interviews), and 6 (consolidation of results).

4 Results of literature-based analysis

4.1 Process description: Identification of a first set of determinants

According to the methodology as described in subchapter 3.2, the process of identifying a first set of LPO determinants based on literature was conducted as follows:

(1) Specify the research question for this part of the research:
The literature-based analysis seeks answers to the first sub-question of the main research question (see subchapter 1.3): *Which LPO determinants can be identified based on previous studies, and how can their influence be described? How can the identified LPO determinants be categorized?*

(2) Searching the pertinent literature:
Relevant literature was identified using the databases and keywords as described in subchapter 3.2.2.

(3) Screening the search results:
The search results were filtered by screening the titles, and the abstracts in a next step. Cited literature (especially in review articles) was also screened.

(4) Assessing the quality of the literature that passed the screening:
The quality of the identified literature was assessed considering criteria such as the publisher (e.g. which journal), target audience, accuracy, depth and breadth of the study, and references. Literature of high quality and high relevance for the research question received stronger attention in the evaluation, and is described in more detail in the following subchapters.

(5) Analyzing literature and transferring identified determinants:
Determinants identified in previous studies were extracted and transferred to the disaster management domain, considering its specific characteristics (see chapters 2 and 4.2.3). For example, a determinant *inter-organizational cooperation* could play an important role in the disaster management domain, because in disaster management it is of utmost importance that different organizations collaborate efficiently.

In addition, several studies that did not explicitly identify determinants but addressed specific aspects of (possible) determinants helped in specifying the relevance and type of influence of

selected determinants. For example, Bastgen (2016) specifically explains possible influences of *employment protection regulations* on innovation processes.

The results of this process are displayed in the following subchapters.

4.2 Private vs. public sector determinants

The majority of innovation management literature principally addresses innovation in private companies, explicitly or implicitly. Yun et al. (2011) explain that innovation processes in the private sector have been researched much more than innovation processes in the public sector (even though new aspects seem to arise for both, the private and the public sector, due to new knowledge and new sources of knowledge for technology innovation). Similarly, Hawi et al. (2018), who conducted a literature review on public and private innovation models, noticed that there is less information available on innovation in the public sector than in the private sector.

However, there are also a number of studies that explicitly analyze specificities of the public sector regarding their innovation activities. Some factors analyzed in the context of the private sector do not play a strong role for the public sector or the field of disaster management specifically, while many other factors can be transferred. Thus, literature dealing with the private sector has been considered as well, and factors have been analyzed in view of the public sector and disaster management context.

4.2.1 Relevant results from studies addressing the private sector

Among the literature addressing the private sector, many studies refer to products targeting the population as consumers, bringing up cultural factors when it comes to the international perspective (e.g., "technology adoption"). There is a whole body of literature on general innovation management or the *diffusion* of new solutions with regard to companies' interest in spreading their products. Tidd and Bessant (2014, 2018) provide an approach to managing innovation in a wide range of contexts, including manufacturing, services, small to large organizations, and the private, public and third sectors (Tidd and Bessant 2014, 2018). Related to this book, there is the open resource "Innovation Portal"[5], which, amongst other things, includes several case studies, searchable by theme (Tidd and Bessant 2016). Another example is a publication by Disselkamp (2012) on innovation management, describing requirements for successfully implementing new ideas in companies (Disselkamp 2012).

A "barriers approach to innovation" has been described by Hadjimanolis (2003). While there are different possibilities for classifying barriers, Hadjimanolis (2003) distinguishes external and internal barriers to innovation. The external barriers include (1) market related, (2) government related, and (3) others, while the internal barriers are (4) people related, (5) structure related, or (6) strategy related (Hadjimanolis 2003). *Market-related* barriers include, for example, market failure such as insufficient appropriability, supply and demand

[5] http://www.innovation-portal.info/ (checked on 24/08/2020)

deficiencies, competition affecting profitability, short-term horizons leading to the neglect of long-term projects, or financial barriers. The second category of external barriers is that of *government-related* barriers ("government and its policies and regulations"). These policies and regulations also encompass those that were actually issued in order to support innovation, but have negative side effects, such as bureaucratic procedures in getting licenses or grants. Since companies have to comply with regulations on different levels, they may discourage innovative activities, increasing uncertainty and risk. Regarding legal constraints, several examples are mentioned: labor and consumer protection legislation, environmental regulation, anti-trust regulation, legislation for protection of intellectual property rights, the tax system, or trade barriers. Barriers can stem from unsuitable laws or regulations, or from inadequate implementation. *Other* external barriers include technical, societal and interorganizational barriers. Technical barriers can, for example, emerge from leading standards. Societal factors refer to norms and values of a society. Interorganizational barriers refer to a lack of cooperation tradition, or a lack of trust. *People-related* barriers refer to perceptions, motivations, skills, or attitudes of managers and employees. In addition, the commitment of higher management and attitudes towards risk are mentioned here. *Structural* factors include inadequate communication flows, or a lack of collaboration between departments, while *strategy-related* barriers address approaches to develop core capabilities and resources (ibid.).

Marinova and Phillimore (2003) also mention the "external environment" as one key element which covers the socioeconomic (including regulatory) environment a solution is developed in. This includes mechanisms such as patent regimes, market structures, standards and regulations (Marinova and Phillimore 2003).

Crossan and Apaydin (2010) conducted a systematic literature review on organizational innovation, focusing on elements that can be controlled by a firm. They find that there is no overarching framework of innovation determinants, and that even previous review papers cover different issues and levels of analysis. "…a lack of a coherent and explicit theoretical base prevails" (Crossan and Apaydin 2010, p. 1164). Consolidating determinants from existing literature, the authors come up with a model that include three main fields of innovation determinants: (1) Innovation leadership (including individual and group levels; e.g. their support and guidance as well as their ability to create supporting conditions); (2) managerial levers (including, e.g., resource allocation or organizational culture); and (3) business processes (including, e.g., project management or commercialization) (Crossan and Apaydin 2010).

4.2.2 Innovation determinants in the public sector

Market mechanisms cannot solely explain innovation processes in public fields, including disaster management, where public benefits and social welfare is the main goal (Yun et al. 2011). Instead, innovation in the public sector has rather been government-led, focusing more on appropriateness than on verification of (economic) efficiency (ibid.).

Typical characteristics that have been assigned to the public sector include being conservative and bureaucratic. It has been seen to be reluctant in implementing innovations, or to implement innovations only in a fragmented way, and only innovations coming from the private sector (Bloch and Bugge 2013; Naranjo-Gil 2009). The most relevant differences between the public and the private sector are their goals and motives. While the private sector mainly seeks profit and efficiency, the public sector mainly aims to increase society's well-being and security.

In addition, most public organizations are not autonomous in their decision-making. "The decision making and organisational structure that public sector organisations operate within are thus central in shaping the conditions for innovation" (Bloch and Bugge 2013, p. 135).

Due to the different goals and motives in the two sectors, the actual drivers for innovation also differ. Main drivers in the public sector are for example seen in political mandates and initiatives from internal actors (both management level and other employees) (Bloch and Bugge 2013). Following Blind et al. (2012), political mandates – as well as new laws and regulations – are top drivers for innovation in the public sector (Blind et al. 2012). While risk aversion, which has often been attributed to the public sector, seems less important, budget restraints, a lack of incentives, lack of time, and legislation have been found to be major barriers in the public sector (Bloch and Bugge 2013; Blind et al. 2012).

Arundel et al. (2019) have analyzed to what extent broadly accepted guidelines on measuring innovation in the private sector could be transferred to the public sector: In its "Oslo Manual", the OECD provides guidelines on how to collect data on innovation in the private sector. The fourth edition was published in 2018 (earlier editions: 1992, 1997 and 2005). The Oslo Manual is used, amongst other things, for the Eurostat Community Innovation Survey (CIS) indicator base, the UNESCO Institute for Statistics (UIS) Innovation Data, and the OECD Innovation Statistics Database (OECD/Eurostat 2018). The guidelines cover a wide range of topics relevant to innovation. Arundel et al. (2019) analyzed in how far the themes covered by the Oslo Manual are also relevant for the public sector. They find that while many issues could be transferred, the background for collecting data differs between the private and the public sector. In order to meet policy needs, public sector surveys on innovation also require information on the way organizations innovate, and on the influence strategic management of innovation has on the types of innovation (Arundel et al. 2019). Additional information required for the public sector includes the source of knowledge/ideas for innovation, the innovation culture, the personality of managers, and the capabilities and tools that are available to support innovation (Eggers and Singh 2009; Arundel et al. 2019).

Among the topics that are relevant both for the private and for the public sector, the importance of specific issues varies between both sectors. This seems to be mainly due to the lack of a profit motive in the public sector. In addition, several issues relevant for businesses are less relevant for the public sector, such as the acquisition of intellectual property rights. In contrast, Arundel et al. (2019) mention the following topics that receive less attention in the

Oslo Manual, but are of most importance for public sector organizations: knowledge sourcing and collaboration with other public sector organizations; management capabilities; the personal characteristics of managers themselves, such as their level of education, previous experience in the private sector, and attitudes to risk; workforce experience with innovation; external factors such as citizen demand for service innovations; and the involvement of customers or end-users in the co-creation of service innovations (Arundel et al. 2019).

Addressing governments that strive to foster innovation in the public sector, the OECD (2017) recommends dealing with four main areas:

(1) People: This area recognizes the importance of public sector employees who can better trigger or push innovation in an appropriate environment, i.e., in an innovation supporting culture, with incentives, and supportive norms.
(2) Knowledge: Internal and external information that is available and used creatively can support effective decision-making and reduce repetitions of mistakes.
(3) Working together: This area addresses the lack of collaboration between organizations and the need to overcome thinking in silos. Dedicated structures and units can help to support innovation through enhanced collaboration.
(4) Supportive rules and processes: Internal rules and processes that aim at mitigating risks should at the same time enable or support innovation. This includes the consideration of possible misperceptions of rules (OECD 2017).

Vries et al. (2016; 2018) conducted a systematic literature analysis on public sector innovation. They find that "antecedents", i.e. drivers and barriers of innovation, identified in literature can be clustered into four categories:

(a) Environmental level: external innovation factors such as political mandates or regulatory aspects, but also relationships to other organizations;
(b) Organizational level: structural and cultural aspects of an organization;
(c) Innovation level: characteristics of an innovation itself such as the "ease-in-use";
(d) Individual/employee level: characteristics of individual employees, i.e. those who can initiate or push forward innovation (Vries et al. 2016; Vries et al. 2018).

Cinar et al. (2019) conducted a systematic literature review, too – on barriers to public sector innovations. They classify the types of barriers into

(i) Organizational barriers: the internal context in which an innovation takes place;
(ii) Interaction-specific barriers: barriers between innovation partners within the innovation process;
(iii) Innovation characteristics related barriers: barriers related to perceived characteristics of an innovation
(iv) Contextual barriers: Barriers such as laws, regulations and policies, or lack of standardization (Cinar et al. 2019).

As already stated in subchapter 1.1.2, a common agreement on how to categorize innovation determinants does not exist. Comparing the categories of OECD (2017), Vries et al. (2016, 2018), and Cinar et al. (2019), similarities and differences can be noted. For example, the category (1) "People" in OECD (2017) to a broad extent corresponds to the category (d) "Individual/employee level" in Vries et al. (2016, 2018). However, the organizational culture is attributed to "People" in the one case, and to the "Organizational level" in the other. In Cinar et al. (2019), these aspects are all collated in (i) "Organizational barriers". While (4) "Supportive rules and processes" addresses issues that would belong to (a) "Environmental level", the latter also includes relationships to other organizations, which OECD (2017) would attribute to (3) "Working together", and Cinar et al. (2019) to (ii) "Interaction-specific barriers".

Characteristics of an innovation itself ("innovation level"/"innovation characteristics related barriers") as identified by Vries et al. (2016, 2018) and Cinar et al. (2019) as a group of innovation determinants, are not among OECD's categories. This might be due to the focus and addressees of the OECD's report, which addresses possibilities of improvement for governments. However, Vries et al. find, compared to the other categories, less empirical attention has been given to characteristics of the innovation itself in the literature (Vries et al. 2016, 2018).

4.2.3 Specificities of disaster management organizations

Besides the public nature of many disaster management organizations (except for some critical infrastructure providers and a few others), there are some specific characteristics of organizations in the disaster management domain that can crucially influence the innovative behavior or ability to implement innovations.

On the one hand, there are specific external conditions that can influence the innovation behavior of disaster management organizations. As described in subchapter 2.2, for some suppliers disaster management is only a relatively small part of their business. Plus, acquisition in the public sector is not centralized, and different needs and capabilities lead to non-coherent purchasing patterns (Martí 2011).

On the other hand, other specific characteristics have also been described. Especially fire services, which possess a strong historical culture, have been seen as quite resistant to change (Allaway 2010). Murphy and Greenhalgh (2018) highlight for the fire and rescue services, that any changes in an organization and its practices require evidence-based and robust justifications. This is partly explained by the fact that the fire services have often been in the position to justify any processes and decisions whenever anything went wrong. Possibly the vital importance of tried and tested routines in firefighting also contributes to the reluctance for change (Schlauderer et al. 2016).

The implementation of a new solution can depend on balancing the new or improved functionalities that the solution would bring with the additional required efforts or restrictions (Schlauderer et al. 2016; Weidinger et al. 2018). "Any gain in functionality will likely have to

be weighed against the additional overload and/or restrictions that arise for the end users" (Weidinger et al. 2018, 669f.). In the context of law enforcement, Lum et al. (2017) find in an empirical study that the perceived efficiency plays a dominant role. If solutions are not assumed to essentially increase efficiency, or do not contribute to the perceived primary tasks of police officers, the introduction of this solution will not be successful (Lum et al. 2017).

In disaster management, where processes need to be conducted under stress and time pressure, solutions need to be easily usable (see e.g. Schlauderer et al. 2016; Weidinger et al. 2018; Turoff et al. 2004; Yang et al. 2009; Lum et al. 2017), in order to possibly "win" the balancing question. In addition, "easy to learn" can also be required (Turoff et al. 2004). Weidinger et al. (2018) also find that, for fire fighters, the perceived compatibility of innovative technologies as well as their complexity are decisive factors for a successful introduction of such technologies in firefighting procedures. Crucial compatibility factors here include simplicity, robustness, and reliability (Weidinger et al. 2018).

This is also related to the specific characteristic of the disaster management domain that disaster response does not happen on a daily or regular basis. Thus, there cannot be any routine for disaster responders. This requires disaster management solutions to be easily usable and/or also being used in non-disaster times on a regular basis (see e.g. Turoff et al. 2004; Yang et al. 2009). This can possibly be solved by integrating day-to-day functions in an envisaged tool or solution (Turoff et al. 2004).

Disaster response demands ad-hoc action, which can only be efficient if required information from various sources is gathered quickly, valid, and provided in a way that is as complete as possible while avoiding information overload (e.g. Turoff et al. 2004; Yang et al. 2009). Disasters can evolve quickly and in unforeseeable ways, which can cause respective requirements for solutions (e.g. allowing changes and adaptations in dynamic manners). Disasters can further strongly differ in type and in the people, organizations and experts involved in managing these disasters. Respectively, an increased coordination demand can occur, including the need to improvise. In addition, disaster management is a continuous action that cannot be paused at any time. These specific characteristics can cause respective requirements for innovative solutions in disaster management (Turoff et al. 2004). In the context of law enforcement, Lum et al. (2017) further mention the possible influence of organizational subcultures, systems, leadership, or officer behavior, but also resource limitations and legal concerns on the effective application of solutions.

4.3 Laws, policies, and organizational innovation determinants in disaster management

In this subchapter, laws, policies, and organizational innovation determinants in disaster management as derived from literature are described. They are based on innovation determinants in private and public sector organizations (see subchapters 4.2.1 and 4.2.2), as well as the specific characteristics of disaster management organizations (see subchapters 2.2 and 4.2.3).

Several studies have provided classifications of innovation determinants, but they differ considerably, see subchapter 1.1.2. Some of them seem to be incomplete for the context at hand, or focus on determinants that are less relevant for the field of disaster management (such as specific market conditions that are only relevant for the private sector, and the general public as their clients). Thus, the following categories have been defined after analyzing existing suggestions for categories (e.g. OECD 2017, Vries et al. 2018, Blind et al. 2012, Hadjimanolis 2003, Thielmann et al. 2009), and additional information on the relevance of specific determinants, as explained under each determinant below.

4.3.1 Laws and policies

Figure 6 provides an overview of the laws and policies identified, which are described in the following. They can be categorized into four thematic groups:

(1) **Information sharing:** laws and policies that affect the handling of data by disaster management organizations, i.e. regulations that govern the use of personal and operational data, and the right for anyone to review documents of governmental organizations.
(2) **Cooperation & knowledge sharing:** IPR regulations; and the existence and actual use of standards that facilitate cooperation.
(3) **Protection of employees & of the organization:** employment protection regulations; liability regulations.
(4) **External incentives:** Laws and policies that support a disaster management organization to enhance its abilities, through funding, political support, or legislation requesting them to act.

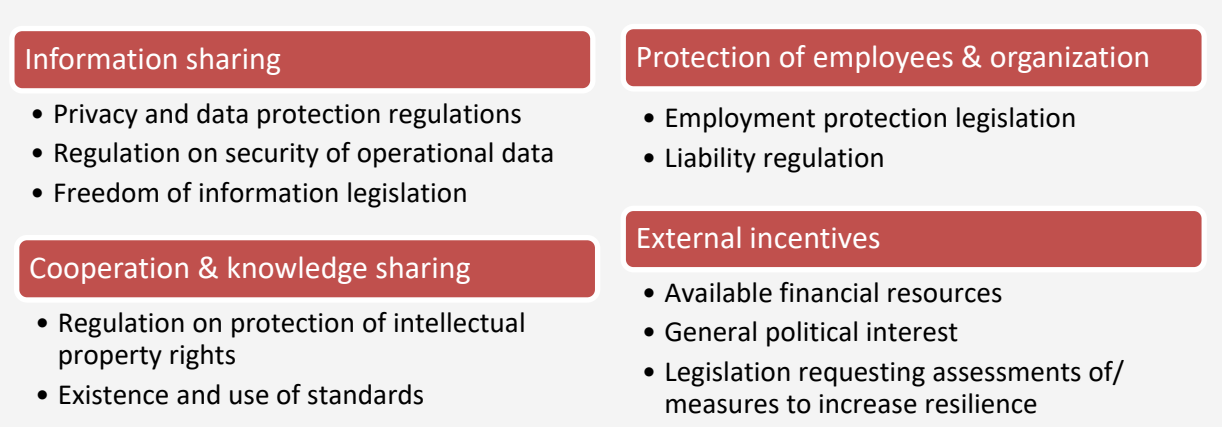

Figure 6: First set of innovation determinants in disaster management to increase resilience – laws, policies

Information sharing

Information sharing seems to be one of the most important fields of innovation determinants in disaster management, since the availability of information at the right time for the right people is highly relevant in disaster management.

Privacy and data protection regulations

Personal information can be crucial for effective disaster management, but at the same time compromise data protection rights. "Even the most sophisticated interoperability solution,

cannot overcome privacy barriers" (Allen et al. 2014, p. 429). Especially in the field of digital and mobile solutions, data protection, including questions of data storage, is an important factor (see e.g. Financial Conduct Authority 2016). It has been criticized that privacy regulations seem subjective to the cultural values and geopolitical climate in a state; that widespread legal uniformity is absent, and a lack of applicable national law on issues of privacy may create legal uncertainty (Cabrera-Alvarado et al. 2013).

An attempt to support legal uniformity is reflected in the comprehensive reform of data protection rules on EU level, which entered into force in May 2016, mainly as a response to challenges arising from the digital age: The main result of this reform is the General Data Protection Regulation (GDPR), i.e., Regulation (EU) 2016/679 – protection of natural persons with regard to the processing of personal data and the free movement of such data. It defines the right of individuals for, e.g., to have easier access to their data that is processed, or a "right to be forgotten" (the data is deleted when there is no longer a need to keep it), or a right to know when their personal data has been hacked. The regulation also defines rules for businesses, e.g. a guarantee that data protection safeguards are built into products and services from the earliest stage (data protection by design and by default), or impact assessments, i.e. businesses have to carry out impact assessments when data processing may result in a high risk for the rights and freedoms of individuals (European Commission 2016b).

Closely related to the GDPR, and also part of the data protection reform, is Directive (EU) 2016/680 – protecting individuals with regard to the processing of their personal data by police and criminal justice authorities, and, on the free movement of such data. It aims to better protect individuals' personal data when their data is being processed by police and criminal justice authorities. It also aims to improve cooperation in the fight against terrorism and cross-border crime in the EU by enabling police and criminal justice authorities in EU countries to exchange information necessary for investigations more efficiently and effectively. The EU Member States had to transpose the Directive into national law by May 2018 (European Commission 2016a). National and international legislation and guidelines further govern how personal data is handled in detail.

A special relevance of data protection concerns in disaster management seems obvious in the health and medical field. Sending pictures of wounded people to disaster room medical staff can provide enormous help, but needs to consider privacy issues (Crowe 2012). Another hurdle that can appear is when national privacy protection laws are not harmonized. For example, if a hospital's patient needs surgery in another country, it has to be figured out which data can be shared under which conditions. It is also relevant if an organization decides or plans to outsource data processing services, conducted in another country (Christin 2011). In the context of social media, personal use by disaster managers is affected as well, since the boundaries of personal and professional use can blur within social media systems (Crowe 2012). Satellite technology for disaster management is an example where privacy has been

identified as a crucial innovation determinant, since it can heavily influence the acquisition of data (Cabrera-Alvarado et al. 2013).

Besides the direct effect of related regulations, also the lack of clarity, i.e., the lack of information on what is allowed and what is not allowed, has an important effect (see e.g. Financial Conduct Authority 2016). Vries et al. (2018) identify concerns about security and privacy issues related to electronic applications as one of the most frequently mentioned innovation-level determinants.

Regulation on security of operational data

In addition to requirements for protecting personal data, which can be relevant in many sectors, the disaster management sector is often also confronted with requirements to secure operational data, especially in the field of law enforcement (Crowe 2012). In the context of information sharing in disaster management, Allen et al. (2014) highlight the handling of classified data as one of the most important barriers. As an example, they find that during the Glasgow airport attack in 2007, response efforts were hindered due to restrictions on what information can be shared (Allen et al. 2014). In addition to the actual restrictions, also uncertainty about what information can and should be shared, and what can and should not be shared is seen as a barrier (ibid.). While confidentiality of data is mandated by law in many countries, the problem remains that convenience and security can often hardly be combined (Christin 2011).

Freedom of information legislation

Freedom of information legislation ensures the right of individuals (and thus also, e.g., journalists) to review public organizations' documents and records. Since this also affects public disaster management organizations, it can influence their behavior, considering the possibility that information can be used to blame an organization for wrong decisions or inappropriate actions during a disaster response. In the social media context, for example, freedom of information legislation is important because most legal experts consider social media as equivalent to other governmental material, so that fulfilling this legal requirement can be challenging for disaster management organizations (Crowe 2012). A prominent example where the "right to know" was breached is the Fukushima nuclear disaster, when during the first days only restricted and distorted information was communicated to the public. This led to a strong lack of trust by the public towards Japanese authorities (Kushida 2012; Alexander 2017).

Cooperation & knowledge sharing

Regulation on protection of intellectual property rights

In the private sector context, it has been found that intellectual property rights can encourage innovation. However, it can also hinder the diffusion of innovations, which possibly restricts further innovations. Thus, the effect on innovations can be twofold (Blind 2016).

In the field of scientific collaboration, Baca (2006) finds that intellectual property rights present a basic hurdle in innovation, and that legal changes could crucially alleviate transaction costs and thus scientific collaboration. In the context of satellite technology for disaster management relief, Cabrera-Alvarado et al. (2013) find that intellectual property rights are not always clear, and not always easy to trace anymore. This is also because different legislation applies depending on the type of work, i.e., if it is information, or an image, or a database, etc. This complicates the sharing of data (Cabrera-Alvarado et al. 2013). In addition, the fact that national regulations on property rights in data differ between countries can impede cross-border data exchange (Maurer et al. 2000). In social media, the use of copyrighted or trademarked materials also presents a complex legal issue. Plus, return on investment (ROI) evaluations are difficult in the context of social media (due to the nontraditional nature of the systems) (Crowe 2012).

Cabrera-Alvarado et al. (2013) raise concerns about satellite imagery that is owned by a few distributors, which means that organizations that require satellite imagery for disaster response need to request and purchase the data. Even though in some cases data can be used for free in disaster response, other phases of disaster management are not covered. Thus, if there are no sufficient guidelines to overcome the issue of costs and terms of usage, this can hinder the proper use of satellite imagery (Cabrera-Alvarado et al. 2013).

Similar to previous determinants, direct impacts of intellectual property rights can be exacerbated by legal uncertainty regarding the use and dissemination of data (Cabrera-Alvarado et al. 2013)

Existence and use of standards

Even though broad empirical evidence is missing, standards and standardization can have different effects on innovation, for example, depending on the innovation phase (supply side; or demand side, including e.g. public procurement), or the degree of market uncertainty (Blind 2013; Blind et al. 2017). Cinar et al. (2019), based on their review on barriers to public sector innovation processes, find that a lack of standards can be a barrier, especially when facing IT or e-government innovations. Also, Basher (2013) mentions a lack of standardization to be one of the major barriers to accept, uptake and apply technology in disaster risk reduction. In the field of satellite technology for disaster management, for example, standards can facilitate the flow and use of data (Cabrera-Alvarado et al. 2013) and thus support an innovative use. On the other hand, Hadjimanolis (2003) in his "barriers approach to innovation" finds that standards may act as hurdles to innovation. One way of explaining the hindering effect of standards on innovation is that "By definition, standardization is about doing things the same way, whereas innovation is about doing things differently" (Hawkins and Blind 2017, p. 1).

Standards can be both "de facto" or "de jure". De facto standards are solutions that are simply widely used, because they are widely accepted, or alternatives are missing. De jure standards have passed a formal process, supervised by a recognized organization (Hawkins and Blind 2017).

Standards in the field of disaster management seem especially relevant due to the amount and diversity of involved organizations that have to collaborate in order to work most effectively.

Protection of employees & of the organization

Employment protection legislation

The effect of employment protection legislation can be twofold: On the one hand, increased job security due to employment protection legislation can increase incentives for the employees, because they would probably profit from the effects of a successful innovation in the future. On the other hand, if the motivations to innovate increase, the risk of failure might also increase, which could lead to stronger hesitations by responsible staff, and thus hinder innovation, especially radical breakthroughs. The actual impact thus also depends on the type of innovation, i.e., incremental vs. radical innovation (Blind 2016; Griffith and Macartney 2014). There is empirical evidence at least in the private sector that employment protection legislation can motivate improvements to existing products, but in contrast can hinder radical innovation (Bastgen 2016; Polat 2016; Saint-Paul 2002).

Since job security is usually higher in the public sector, this factor might play a specific role in disaster management.

Liability regulation

While liability regulations can support the acceptance of an innovation by the public, and thereby its diffusion, strict liability regulations can also hinder people and organizations to innovate (e.g. Blind 2016). For instance, legal liability can be an issue in the context of emerging technologies, such as artificial intelligence. A difficult question is who should be held accountable if artificial intelligence fails and leads to undesirable consequences or wrong decisions (House of Lords Select Committee on Artificial Intelligence 2018). In the context of disaster risk, a well-known example of when the question of legal liability led to intense discussions is related to the earthquake in l'Aquila, Italy, in 2009. Seismologists were accused and even imprisoned, because they had not predicted the earthquake, in contrast, they had assured that a huge earthquake would be unlikely a few days prior to the earthquake (Benessia and Marchi 2017). As another example, liability for the accuracy of data can result in a reluctance of parties to share data (internationally). Data that is inadequate or not provided as timely as required runs the risk of hindering relief efforts when relied upon (Cabrera-Alvarado et al. 2013).

External incentives

Available financial resources

Regarding the relationship between available resources and the general innovativeness of public organizations, results of research activities are twofold (Demircioglu and Audretsch 2017; Buchheim et al. 2019): On the one hand, it has been found that a lack of resources can trigger innovative behavior if public agencies are asked to do the same job using fewer

resources (see e.g. Demircioglu and Audretsch 2017). For example, Glor (2001), Sahni et al. (2013), or Wynen et al. (2014) found that, in many examples, budget scarcity in the public sector has been a main driver of innovation. On the other hand, the introduction of new solutions can require additional resources, and if resource scarcity is low, the probability that proposals to spend resources on innovations will be accepted is higher (e.g. Demircioglu and Audretsch 2017; Fernández and Wise 2010). Also the literature reviews by Vries et al. (2018) as well as Cinar et al. (2019) identify the availability of resources to be among the most frequently mentioned organizational determinants in literature on public sector innovations, i.e., money, staff, and ICT facilities are often required for successful innovation implementation (Cinar et al. 2019; Vries et al. 2018). Since any innovation implementation means some kind of organizational change, appropriate resources are required for each step in the change process, including the development of a plan, required communication actions, training, reorganization, or testing the innovation. Resource scarcity can therefore hinder innovation (Fernandez and Rainey 2006). Also for the application of science and technology to reduce disaster risk, Basher (2013) finds that a lack of reliable sustainable funding presents a common barrier. Also León et al. (2012) identify both a shortage of financial resources as well as an availability of financial resources as possibly presenting important drivers to public sector innovations (León et al. 2012). Potentially, the direction of influence depends on the amount of available financial resources: Nohria and Gulati (1996) claim that with increasing slack (i.e. resources in an organization that is in excess of the minimum necessary) innovation increases, up to a tipping point, and decreases from there. This would mean that both too little and too much available resources hinder innovation.

Besides the general availability of resources, the specific costs and dedicated budget for a specific innovation present a relevant determinant – see determinant *Costs* under "Compatibility of innovation-specific characteristics" in subchapter 4.3.2.

General political interest

A lack of political interest or awareness is often a main hurdle to the use of science and technology in disaster risk reduction (Basher 2013). In relation to the determinant *Commitment of individuals*, the sustained support of politicians, amongst others, can be critical to gain the required backup of implementing an innovation (e.g. León et al. 2012; Fernandez and Rainey 2006). While *Commitment of individuals* relates to the commitment of individual persons, this determinant refers to the overall climate on a political level that can encourage politicians to support specific innovations, for example, triggered by societal developments or specific public opinions and perceptions. A tendency has been detected that political interest is high in early phases of new technology, while it quickly vanishes if there are no visible results after a few years – which can be obstructive, because these technologies might need political support even more if companies start to limit respective research and development activities (Thielmann et al. 2009).

Legislation requesting assessments of/measures to increase resilience

Legislation requesting an organization to act can push innovation activities, even though the question remains open of whether driving innovation in the public sector top down by law or rather bottom-up is more effective (León et al. 2012). The "push effect" of legislation has been introduced in subchapter 1.1.3, as one of several possible effects of LPO factors on innovation (e.g. Männer et al. 2012). For example, a new law on production processes, or changes in labeling obligations for food additives can trigger innovation in these fields (ibid.). In the context of critical infrastructure, a possible solution to enhance the resilience of critical infrastructure is seen in regulations that require periodic audits of all accesses. Legal demands on operators of critical cyber-physical systems to provide adequate levels of security for their assets could also be beneficial. One way of implementation would be a certification process of computing infrastructure (Christin 2011). In the context of disaster management, this could refer to any new legislation that has been established in order to increase the resilience of society by means of enhanced disaster management.

4.3.2 Organizational determinants

Many studies have addressed organizational characteristics that influence an organization`s innovation capability. In most cases they address the private sector (e.g. Brem et al. 2019; Smith et al. 2008), but a lot of work has also been done on public sector organizations.

In the context of private sector organizations, for example, Smith et al. (2008) conducted a comprehensive systematic literature review. From the vast amount of literature, they draw nine main factors that influence an organization's ability to manage innovation: Technology, Innovation process, Corporate strategy, Organizational structure, Organizational culture, Employees, Resources, Knowledge management, Management style and leadership (Smith et al. 2008).

For public sector organizations, for example, Fernandez and Rainey (2006), based on a comprehensive literature review, identify eight factors regarding the question as to what "managerial leaders" should do to successfully manage organizational change: (1) Ensure the need, (2) Provide a plan, (3) Build internal support for change and overcome resistance, (4) Ensure top-management support and commitment, (5) Build external support, (6) Provide resources, (7) Institutionalize change, and (8) Pursue comprehensive change (Fernandez and Rainey 2006).

Some studies have tried to relate general organizational characteristics to innovation behavior. For example, an organization's overall strategy can reflect the attitude towards innovations and organizational changes. However, clear evidence is missing (Naranjo-Gil 2009). Bloch and Bugge (2013) even assume that innovations are usually responses to specific problems, rather than a part or result of an overall strategy (Bloch and Bugge 2013). Another general characteristic, the size of an organization, was claimed to be related to innovation behavior. Bigger organizations can have better access to required resources, or have more sophisticated information and control systems, so they might be more open to innovations in this field.

However, it seems that too many other factors play a role, and clear evidence is missing (Chenhall 2003; Naranjo-Gil 2009).

Organizational innovation determinants are strongly related to drivers and barriers to "organizational change", which has been dealt with by many authors (e.g. Cohen and Sproull 1996; Hannan and Freeman 1984; Tidd and Bessant 2018; Tidd et al. 2006; Senior and Swailes 2016; Tushman and O'Reilly 2002), mainly addressing the issue that "managing organizational change is problematic largely because human beings are programmed to resist or at least be cautious about change" (Tidd et al. 2006, p. 397).

Based on literature that addresses organizational innovation factors in general as well as literature analyzing specific determinants, the following determinants have been identified, which can be categorized into four thematic groups:

(1) **Staff and work process:** Characteristics of staff including management level, work processes related to the internal structure and regulations.
(2) **Intra- and interorganizational cooperation and communication:** Practices and characteristics of intra- and interorganizational cooperation and communication.
(3) **Innovation culture:** The general attitude in an organization towards innovation and changes.
(4) **Compatibility of innovation-specific characteristics:** Characteristics of a specific innovation and how they fit to the organizational conditions.

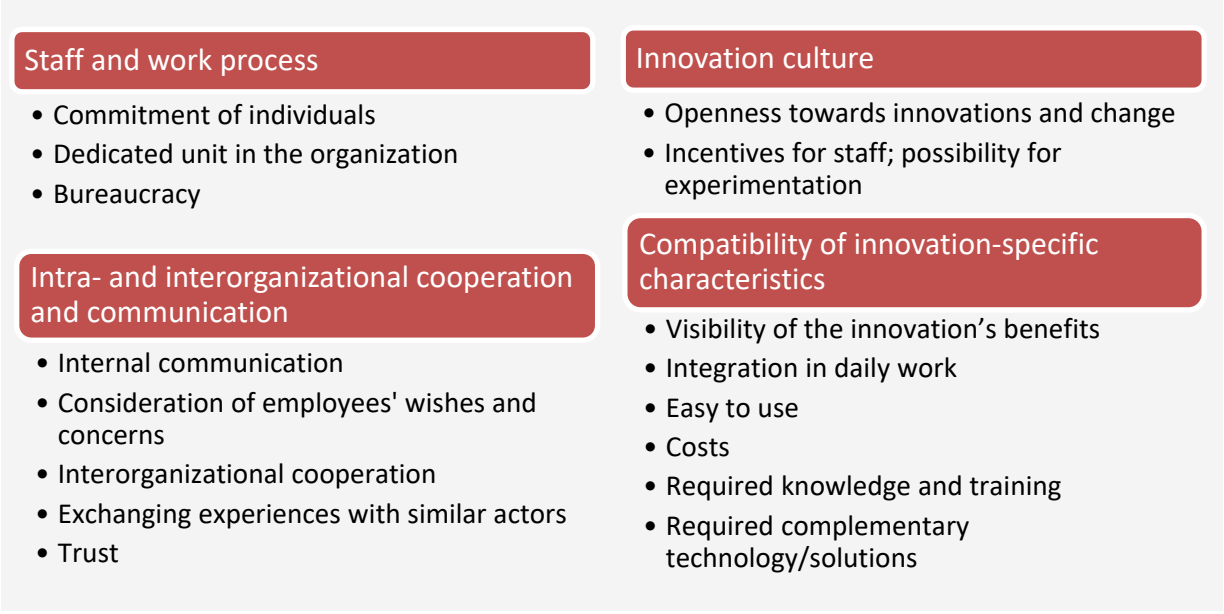

Figure 7: First set of innovation determinants in disaster management to increase resilience – organizational factors

Commitment of individuals (management level; staff; elected officials)

The commitment or engagement of staff pushing an innovation has strong effects. In the private sector, the effect on profits and business success was shown – for employees in general (see e.g. Bakker 2011; Rayton et al. 2012; OECD 2017), and for the top-management level

specifically (see e.g. Sattayaraksa and Boon-itt 2012; Cooper 2003; Rodríguez et al. 2008; Sedighadeli and Kachouie 2013). In the public sector, amongst others, a comprehensive literature review by Vries et al. (2018) identified "supportive leadership" to be one of the most frequently mentioned factors for successful innovation, referring to e.g. Borins (2002), Gagnon et al. (2012), and Wallis and Goldfinch (2013). Also León et al. (2012) find that "Leadership and good management" can play an important role for innovations in the public sector, based on a cross-country analysis in the EU. Fernandez and Rainey (2006) confirm that top-management support and commitment is important to organizational change in the public sector, but also refer to the importance of either an individual or a group within the organization that "champions" the change. Even if other pre-conditions are given, such an "innovation champion" can be decisive for turning an approach into real action (León et al. 2012).

Reasons for the high impact of the commitment of relevant persons are seen in stronger personal initiatives by committed people, as they are more involved and socially connected to their work, which increases their abilities to innovate (Rayton et al. 2012; Fernandez and Rainey 2006). It has been found that motivation and engagement leads to better work performance, making more of an effort and more willingness for change in the organization (OECD 2017). Vries et al. (2018) even define, based on their literature review, a separate factor "personality characteristics", referring to characteristics such as autonomy, enthusiasm, or charisma (Vries et al. 2018).

Besides internal support, be it top-management or other staff, the support and/or commitment of relevant external individuals is crucial in many cases. Reasons for the (sometimes) high impact of external support can be seen in the possibility of regulatory changes and the ability to provide required resources (Berman and Wang 2000; Fernandez and Rainey 2006).

Due to the strong relation between commitment of management level, commitment of external key stakeholders, and personality characteristics of persons involved in the innovation process, they are combined under this determinant *Commitment of individuals*.

Dedicated unit in the organization

A dedicated place for knowledge, expertise, resources, and tools can ensure that the required resources are available. The lack of an own R&D department can be an important barrier to innovation (Hadjimanolis 2003). A chapter in an OECD report (OECD 2017) addresses organizations supporting innovation, i.e., dedicated units or teams. In contrast to the determinant at hand, the report does not address units within an organization, but external organizations dedicated to support innovation. However, the impacts are similar: The teams or units can compensate for a lack of other prerequisites, such as missing change leaders, rewards or other incentives, and provide a safe space for experimentation (OECD 2017). In the context of disaster management, this factor seems especially relevant because the majority of public disaster management organizations do not have resources for a dedicated unit at their disposal. A dedicated unit is also related to staff possessing specific skills in innovation, which is often lacking (León et al. 2012).

Bureaucracy

Bureaucracy is often seen as one of the main barriers to innovation in the public sector. In the narrow sense, it refers to internal rules and procedures, while the wider context is just as important, i.e., assumptions and behavior caused by the internal rules and regulations (OECD 2017). There is scientific evidence that it is often not the regulations themselves, but their interpretation that hinders innovation (Kruiter and De Jong 2008; Cels et al. 2012, cited in OECD 2017). Employees sometimes – consciously or unconsciously – interpret the rules more strictly than they actually are. Principally, bureaucracy is a result of values that government and society try to uphold, such as rational decision-making, effectiveness, transparency or fairness. Respective regulations and procedures have been created to help try to uphold these values. While the targeted values usually do not contradict innovation, it can happen that the respective regulations and procedures – or their interpretation – do hinder innovation. Research has raised concerns that opportunities for innovation might be missed due to bureaucratic hurdles that actually do not serve their original purpose anymore (OECD 2017). Thielmann et al. (2009) identified bureaucracy to be one of the main hurdles to establishing key technologies in Germany. Cinar et al. (2019) identify in their review "inappropriate organizational structure and culture", which includes slow bureaucracy, to be one of the main hurdles to public sector innovation.

Intra- and interorganizational cooperation and communication

Internal communication

Basher (2013) mentions common competition and lack of communication between sectors and departments of state, which constitutes a barrier to acceptance and use of new technology (Basher 2013). In general, information flow, including searching for, processing, and transferring information, is an important part in an innovation process (Hauschildt and Kirchmann 2001; Rogers 1982). Thus, for example, Hadjimanolis (2003) explains inadequate communication flows to be one of the main structural internal barriers to innovation (Hadjimanolis 2003). The need for change through implementation of the envisaged innovation needs to be communicated persuasively. Both other members of the organization and relevant external actors need to be convinced. It is thereby useful to create a vision or picture of the future that is appealing to the addressees (Fernandez and Rainey 2006). Such good communication can also enhance the *commitment of individuals* (see above). In addition, while communicating the need, it is important to listen to the *employees' wishes and concerns* (see below) at the same time, and to involve them in the process.

Consideration of employees' wishes and concerns

A successful implementation of new solutions in an organization also depends on the employees and their attitude towards the innovation. For example, Piderit (2000) emphasizes the importance of the workforce for change. If the wishes and concerns of employees are not addressed or even ignored, this can have strong effects on the actual implementation and application of an innovation (Stolk et al. 2012). Considering employees' wishes and concerns

is therefore required to build internal support. Possible approaches include offering job security, employee participation in the innovation process, recognition of past practices, and gradual innovation implementation (Fernandez and Rainey 2006).

Interorganizational cooperation

Collaboration with external stakeholders and/or other organizations can be crucial for co-creating new solutions. In the private sector context, a lack of cooperation tradition was found to be problematic in vertical terms, i.e., along the supply chain, as well as in horizontal terms, i.e., among firms of the same sector, e.g., caused by a lack of trust (Hadjimanolis 2003). Inadequate communication between different public organizations involved in an innovation process was reported to possibly hinder innovation as well (Dorado and Vaz 2003; Cinar et al. 2019).

Disaster management usually requires cooperation and communication between different types of organizations, for example, rescue services, fire brigade, police, or critical infrastructure providers. The interaction of different organizations at different levels increases the complexity of a crisis situation (Kapucu 2009; Roche et al. 2013), which, in turn, challenges communication. It has been found that organizational differences, for example differences in working methods and terminology, hierarchies, but also underlying cultures, norms and values, often create communication barriers (Fischer et al. 2016). Different organizational competences and cultures among different public sector organizations involved in an innovation process have been identified as possible barrier (Cinar et al. 2019). Also Allen et al. (2014) find that a lack of a "common language" presents a crucial factor hindering information sharing and interoperability in disaster management (Allen et al. 2014).

Exchanging experiences with similar actors

Interorganizational cooperation can also be important for learning, since networks of organizations can lead to learning from each other (Sørensen and Torfing 2011; Hadjimanolis 2003). Exchanging experiences, getting to know about previous experience with introducing a specific new solution, related possible requirements or barriers, can be extremely supportive. In this context, Vries et al. (2018) identified "Learning" through interorganizational networks to be one of the most frequently mentioned determinants in literature. Also the presentation of role models/best practice examples are opportunities both for triggering innovative behavior, and for learning from the experience of other organizations (León et al. 2012). Cinar et al. (2019) in their review identified a lack of knowledge sharing between public sector organizations as belonging to the group of main interaction-specific barriers to public sector innovation.

Trust

Communication barriers as mentioned above can lead to a lack of trust – and/or the other way around, i.e., a lack of trust can hinder communication and cooperation between related organizations (Fischer et al. 2016; Hadjimanolis 2003). Trust was also among the main reasons identified for problems in interorganizational disaster response to Hurricane Katrina and Rita

in 2005 (Kapucu et al. 2010). "Turf fights" were reported in this context as well (Cinar et al. 2019). A lack of trust presenting a possible barrier to innovation has been identified both among employees within an organization (see e.g. Buchheim et al. 2019) as well as between organizations (see e.g. Cinar et al. 2019). Since activities in disaster management seem to be based on personal networks or individual initiatives in many cases, trust is assumed to play an essential role.

Innovation culture

Openness towards innovations and change

Being open towards innovations is closely related to a general resistance to (organizational) change. In the context of organizational theory, the "stickiness" of organizations has been described (Boettke et al. 2008). It has also been called "structural inertia", which can be caused by concerns regarding, for example, costs, political will, legal barriers, or the fear of loss of legitimacy as a result of radical changes. In their systematic literature reviews, Cinar et al. (2019) as well as Vries et al. (2016; 2018) find that the individual attitude towards an innovation's implementation, often described through resistance to change, is highlighted in many studies, and thus ranks among the most important determinants. Key sources deal with human decision processes, i.e., theories of behavior, attitude, belief and intention (Ajzen 1991; Fishbein and Ajzen 1975). Besides individual characteristics, whether an organization is open towards innovations also depends on the organizational climate, e.g., if creativity is supported and encouraged (e.g. León et al. 2012; Tang and Yeh 2015; Shanker et al. 2017; Tidd et al. 2006). Established and intensively used routines and structures can also hinder change (Hannan and Freeman 1984). Routines can be very useful and important in disaster situations, which seems to be one of the reasons for limited changes in disaster management organizations. For fire brigades, which traditionally own hierarchical and conservative structures, it was found that a necessary familiarity with working equipment and structures leads to a cautious attitude towards change, and that change thus happens only very slowly (Bilhuber 2012).

In the context of innovation culture, the learning culture in an organization has been identified to be supportive for innovation processes as well (Cinar et al. 2019; Marsden et al. 2011). This aspect is covered under the determinant *Required knowledge and training*, related to specific innovation processes.

Incentives for staff; possibility for experimentation

The motivation of staff to innovate can be intrinsic, i.e., based on personality (see above, determinants *commitment of individuals*, and *openness towards innovations*), but also respective working conditions can trigger or support innovative behavior. These are strongly related to the organizational climate and the general openness towards innovation of the organization, and also to management (see also OECD 2017). Working conditions that include incentives for innovative behavior can encourage staff to innovate, and support innovation initiatives (León et al. 2012). "Hence, organisations must offer the right incentives to motivate the right

behaviour" (Boxall and Purcell 2011 cited in OECD 2017). While remarkable financial rewards have been granted for innovators in the private sector, there have not been comparable financial rewards in the public sector (Borins 2006). However, smaller financial rewards or other types of recognition/awards can be an effective way to encourage innovation (ibid.). Creating incentives is hence included in the main actions that OECD has identified for governments to address, in order to foster innovation (OECD 2017). It is suggested that creating incentives should also be addressed through human resource management, in order to support innovative actions (Laursen and Foss 2013; OECD 2017). Innovative behavior can also be triggered by motivations to improve performance of the organization (Demircioglu and Audretsch 2017).

Innovations often require possibilities for experimentation, and to accept and learn from mistakes, in order to evaluate, adapt, validate or drop new ideas (ANAO 2009; Borins 2001). The fear of failing and the related costs often hinder innovative actions. "Innovative organizations, however, do not avoid errors" (Borins 2001, p. 318). It has also been noted that an organizational environment that encourages experimentation, has positive effects on employees' motivation and supports them in their capabilities and enjoyment of their work, which again supports innovative behavior (Marfleet 2008; Demircioglu and Audretsch 2017). Thus, encouraging experimentation can increase innovations (see also Dawson and Denford 2015). Possibilities for experimentation, including possible failures, requires a respective risk culture within the organization, which Vries et al. (2016; 2018) also found in their systematic literature analysis on public sector innovation ranking among the most important determinants (Vries et al. 2018). "Triability" is mentioned in the same study, under innovation-specific factors (Vries et al. 2018).

Compatibility of innovation-specific characteristics

Visibility of the innovation's benefits

Benefits of the innovation need to be visible. In the context of public health agencies, for example, it was found that "…innovations most likely to be implemented are those that present a clear value proposition to agencies…" (Baseman et al. 2018). Also Vries et al. (2018) find that the "relative advantage/perceived usefulness" is identified in many studies to be a crucial innovation factor. Rogers (2003) (and already Davis (1989), in the context of IT), who is often cited in the context of innovation diffusion in the private sector, point out that the perceived advantage is much more important than the "objective" advantage, which might be measurable in economic terms. (See also *Internal communication.*)

Integration in daily work

Regarding innovation related characteristics, Vries et al. (2018) as well as Cinar et al. (2019) in their literature reviews find that (in)compatibility is one of the most cited determinants. An innovation should be "consistent with the existing values, past experiences and needs of potential adopters" (Rogers 2003). This is required for an innovation to be adequately integrated in daily work. Fernandez and Rainey (2006) call it the need to "effectively

institutionalize and embed changes" (Fernandez and Rainey 2006, p. 172), by incorporating them into daily routines in order to routinize new behaviors. The determinant is especially important in disaster management since disasters do not occur daily. For example, it was found that an emergency response system will only be used in an actual emergency if it has been used on a regular basis before the emergency (Turoff et al. 2004; Yang et al. 2009). Depending on the nature of the considered innovation, this might require identifying and integrating day-to-day functions in the solution (see e.g. Turoff et al. 2004).

Easy to use

Rogers (2003) defined five "perceived attributes of innovations" to explain different rates of innovation adoption in the private sector: relative advantage, compatibility, complexity, triability, and observability. In the public sector literature, compatibility and ease of use are often mentioned (Vries et al. 2018). "Ease of use", i.e., an innovation being easy to understand and designed in a user friendly way, is the most frequently mentioned innovation antecedent in the review of Vries et al. (2018) on the diffusion and adoption of public sector innovations. Cinar et al. (2019) find that next to compatibility, complexity is one of the most cited barriers among innovation-specific characteristics. Especially for software and platforms, complexity has been identified as a crucial barrier to innovation implementation (Cinar et al. 2019). Complexity can hinder a solution from becoming easy to use.

In disaster response, where actions are conducted ad hoc, under stress and time pressure, and possibly without people being used to any solution that is applied, it can be of utmost importance that an innovation is easy to use (see e.g. Schlauderer et al. 2016; Weidinger et al. 2018; Turoff et al. 2004; Yang et al. 2009; Lum et al. 2017). Weidinger et al. (2018), for instance, found in a study on the acceptance of new information technologies by firefighters that especially the perceived compatibility and complexity can prevent an innovation from being accepted. Thereby, simplicity presented a most crucial factor, i.e. a system needs to be simple and intuitively usable.

Costs

While the general availability of resources (see also *Available financial resources* under "External incentives") seems to have (positive or negative) influence, the success of a specific innovation implementation can also depend on its individual costs, and/or the availability of required resources dedicated to the innovation (e.g. Greenhalgh et al. 2004; Fernandez and Rainey 2006; Thielmann et al. 2009). Also Vries et al. (2018) identify "costs" of an innovation's implementation on the innovation-level to be a relevant determinant, in addition to the slack resources on organizational level. In general, the higher the costs of an innovation, the more challenging its implementation can be. However, switching costs has also been identified as possibly hindering effective implementation (Cinar et al. 2019).

Required knowledge and training

The introduction of a new tool or way of working may require adequate knowledge and/or training for those who are supposed to apply the new solution. Training has been identified

as one of the main human resource management factors relevant for implementing an innovation (Greenhalgh et al. 2004). Also Cinar et al. (2019) in their literature review identify a lack of training (referring to Abuya et al. 2012) as well as a lack of support for end users (referring to Gardner et al. 2010) as potential barriers to public sector innovation. "Training/support for employees" has also been identified as one of the most frequently mentioned organizational factors in literature by Vries et al. (2018). Applying technology in disaster risk reduction requires adequate knowledge and training, too (Basher 2013).

Required complementary technology/solutions

Depending on the nature of the innovation, complementary technology or other pre-conditions might be required (e.g. Thielmann et al. 2009). Cinar et al. (2019) and Vries et al. (2018) find that "compatibility", i.e., the innovation being in line with existing procedures in the organization, constitutes an important and frequently mentioned factor, while many studies cite the work of Rogers (2003) (Vries et al. 2018). However, Rogers (2003) understands the perceived compatibility as "the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters" (Rogers 2003, p. 15), while this determinant is more in line with the understanding of compatibility by Weidinger et al. (2018) as "the extent to which an innovation is viewed as consistent with preferred practices" (Weidinger et al. 2018, p. 673). The perceived compatibility has been identified to be an essential factor for the acceptance of new information technologies by firefighters (ibid.). Some innovations also require additional changes in the organization – e.g. a new technological solution that is only efficient if working procedures are adapted as well (e.g. Lum et al. 2017).

4.4 Summary of literature-based analysis

Literature addressing innovation implementation both in the private and the public sector has been analyzed, and a first set of determinants has been derived considering the specific characteristics of the disaster management sector. This included considering both the external setting such as the general structure and market conditions of disaster management in the EU (chapter 2) as well as intrinsic specificities of disaster management organizations that directly determine innovation implementations (4.2.3). This first set of laws, policies, and organizational innovation determinants in disaster management is displayed in Figure 6 and Figure 7, and includes in total 26 determinants, clustered in eight thematic groups: Laws and policies are categorized into "Information sharing", "Cooperation & knowledge sharing", "Protection of employees & of the organization", and "External incentives". Organizational determinants belong to "Staff and work process", "Intra- and interorganizational cooperation", "Innovation culture", and "Compatibility of innovation-specific characteristics".

This first set of determinants feeds into the expert interviews (chapter 5). Through the expert interviews, the role of the determinants in example cases of innovation implementations in disaster management will be analyzed. Plus, additional aspects not yet reflected in the first set

of determinants will be analyzed. This will finally lead to validation, adaptation, or change of the determinants (chapter 6).

5 Results of expert interviews

In this chapter, results of the expert interviews are presented. First, the selection of innovation examples and experts for the interviews is described (subchapter 5.1), as this was the basis for the interviews. The process of evaluating the interviews is explained in subchapter 5.2, followed by subchapters on the results, i.e., one subchapter per innovation (subchapters 5.3 – 5.9).

5.1 Selection of example innovations and experts for interviews

Identifying suitable examples of innovative solutions in disaster management is not trivial, especially considering that innovation is generally limited in this field. There were considerations on whether to conduct interviews on unsuccessful innovation processes as well. But this approach would firstly have required possibilities to discover such unsuccessful attempts, and secondly the possibility and willingness of persons involved to be interviewed. Plus, the identification of causality would have been even more difficult (e.g., it seems impossible to prove that there was a real attempt). A "successful" implementation, however, did not explicitly represent a criterion for selection. Irrespective of the level of "success" of an implementation, both the factors that support an implementation and those that hinder an implementation have been analyzed.

Approaches and sources for identifying suitable examples are described in the following. Then, the selection of examples according to the selection criteria as introduced in subchapter 3.3.2 is explained.

5.1.1 Identification of implemented innovations

Since there is no database or any other source that collects information on all innovations in disaster management, the example solutions needed to be identified using other sources. Using the "ten most crucial innovations in disaster management in the last years" was considered. This turned out to be impossible, since there are no "*the* ten most crucial" innovations. The definition would have been a subjective one, also because innovation often takes place on a lower level, affecting only one organization at a time. Another option seemed to be using "current trends in disaster management". But also here, *the* trends could not be identified, at least not scientifically. There are currently attempts to apply some overall trends of (technological) solutions in the disaster management domain, such as artificial intelligence and machine learning. However, these do not represent examples of solutions that have already been implemented and used in a way that relevant experience was available for the thesis.

Since it can be expected that crucial innovations in disaster management receive interest from researchers and/or the media, a general internet and literature research was conducted to

identify possible example innovations. This included screening websites and reports of disaster management organizations in EU countries, in order to reveal whether webpages or, e.g., annual reports of these organizations describe new equipment that has been purchased in the past year, including simple replacements of old tools, or stockpiling of existing equipment, but possibly also completely new tools or processes. However, useful examples could not be identified in this way. For example, one webpage included a detailed description of vehicles and equipment/tools. It was however not distinguishable, if or which of them had just recently been implemented. In another example, one annual report includes a description of investments, e.g., for different kinds of vehicles. It seems however that old vehicles or equipment had been substituted or improved, rather than implementing actual new tools.

Pertinent databases in the EU were also analyzed: information on purchased products, as included on the website of Tenders Electronic Daily (TED)[6], which is dedicated to European public procurement, can reveal who has purchased which product and from whom. This information was screened for "new" solutions in disaster management. The TED database publishes public procurement notices, which include different types of documents related to procurement processes, such as contract notices (calls for competition), and contract award notices (notices on the results of the procurement procedure). The search in the database was conducted in the following way: Regarding types of document, the focus was on contract award notices, since as a first priority, information on those solutions is of interest that have actually been purchased. However, other types of documents can also contain useful information and were scanned as well. The documents in TED are further assigned to different business sectors. Under the category "Defense and security", the following sectors and sub sectors were chosen:

- Security, fire-fighting, police and defense equipment
    - Emergency and security equipment,
        - Firefighting, rescue and safety equipment
            - Firefighting equipment
            - Firefighting, rescue and safety equipment
            - Rescue and emergency equipment
        - Emergency and security equipment
    - Security, fire-fighting, police and defense equipment
    - Police equipment
- Training services in defense and security materials
    - Training and simulation in security equipment
- Research and development services on security and defense materials

It is further possible to search by contractor name, using keywords. The following keywords within contractor's names were used: "Fire", "Police", "Rescue", "Emergency", and "Relief".

[6] © European Union, http://ted.europa.eu, 1998–2018 (checked on 12/06/2018)

The screening revealed that in the considered cases it was not clear if a purchased product is "new" or not. A personal request to the TED help desk confirmed that such information is not available. In addition, in some cases the information provided is scarce, and/or only available in foreign languages.

Other databases were checked, too: CORDIS[7], the Community Research and Development Information Service of the European Commission, provides information on EU projects. It does not, however, provide information on actually implemented project results. The Innovation Radar[8] of the European Commission provides information on innovations, including the respective "innovators", stemming from EU projects. It was not possible to identify actually implemented project results in the field of disaster management, which is possibly due to the fact that the radar was still quite young at the time of investigation.

Further investigations were carried out into whether initiatives that support public procurement of innovations can provide examples. In Germany, the Competence Center Innovative Procurement of the Federal Ministry for Economic Affairs and Energy[9] provides support for innovative public procurement, and offers a database of examples (Competence Center Innovative Procurement 2019). An analysis of this database plus personal consultation (February 2019) revealed, however, that these innovation examples do not include any examples in the field of disaster management. On EU level, public procurement of innovative solutions is also supported, especially through different possibilities of funding. A list of EU funded public procurement of innovative solutions is provided by the European Commission on a website (European Commission 2019). These examples also cover the field of disaster management. However, the funding is dedicated to the development of respective solutions, and thus the actual implementation remains open.

The difficulty of identifying suitable examples of innovation possibly mirrors the hypothesis that innovative actions, and especially the actual implementation of innovations, are scarce in the field of disaster management. Nevertheless, examples of innovative solutions in disaster management were successfully identified. This was possible especially via conferences and fairs, where innovations are presented or exhibited (Europäischer Katastrophenschutzkongress, Security Essen, INTERSCHUTZ). This was complemented by directly contacting pertinent organizations, which supported the identification of possible examples.

5.1.2 Selection of innovations

The criteria for selecting example innovations were introduced in subchapter 3.3.2, and comprise (1) Covering different types of innovations, (2) Timeframe of implementation, (3)

[7] https://cordis.europa.eu/ (checked on 12/06/2018)
[8] https://www.innoradar.eu/ (checked on 12/06/2018)
[9] https://www.koinno-bmwi.de/en/koinno/ (checked on 20/03/2019)

Being "new", and (4) Relevance for other organizations. Based on these criteria, seven solutions were selected (four in Germany, two in Austria, and one in the Netherlands).

Table 3: Overview of selected innovations

Innovation	Short description
(A) National crisis management system	Introducing a national crisis management system in the Netherlands. It includes a common IT system as well as new working procedures.
(B) Staff unit on Research and Innovation (R&I) management within a governmental civil protection agency	Establishing a staff unit dedicated to R&I management at a governmental civil protection agency in Germany. The unit was established in 2015, and became part of management staff in 2018.
(C) Innovation cluster	Establishing a cluster of German disaster management organizations for joint innovation actions in the field of civil security research.
(D) Cooperative control center	Introducing a cooperative control center, jointly operated by 3 German counties *(Landkreise)* (since 2001). It is dedicated to rescue services, the fire brigade as well as the police (since 2010). It includes a new functional building as well as compatible IT systems for daily operational control and for disaster management (since 2018).
(E) Compatible disaster management IT system	Introducing compatible IT systems for daily operational control and for disaster management at a federal state level in Austria. The disaster management system receives information from subsystems – amongst others from the IT system for daily operational control.
(F) Drone	Using drones to support firefighting. Drones have been adapted and further developed for use by a fire brigade in a big city in Germany.
(G) Warning system	Implementing a warning system that enables government agencies and safety and security organizations in Austria that operate the system to send public warnings and behavioral advice to citizens via digital information channels, especially a smartphone app.

Table 3 provides an overview of these selected innovations.[10] Then, Table 4 and Table 5 encompass descriptions on how the innovations meet the criteria (1)-(4).

The following describes how these innovations meet the criteria for the selection of innovations as defined in subchapter 3.3.2:

[10] For reasons of anonymity, exact names of solutions and the interviewees' organizations are avoided.

(1) Covering different types of innovation

The coverage of the main types of innovation, i.e., according to content and according to the degree of innovation, is presented in Table 4.

Table 4: Innovation per type

Innovation	Product innovation	Organizational innovation	Fundamentally new innovation	Innovation improving product/process	Innovation imitating existing products
(A) National crisis management system	x		x		
(B) Staff unit on R&I management within a governmental civil protection agency		x		x	
(C) Innovation cluster		x			x
(D) Cooperative control center		x	x		
(E) Compatible disaster management IT system	x			x	
(F) Drone	x				x
(G) Warning system	x		x		

Table 5 presents how the innovations meet the criteria *(2) Timeframe of implementation*, *(3) Being "new"*, and *(4) Relevance for other organizations.*

As mentioned in subchapter 3.3.2, while focusing on EU countries, covering specific countries was not part of the selection criteria. Thus, a comparison of different countries is not conducted here, however, identified aspects are related to the countries' specific context, if applicable. The Netherlands for example, representing a relatively small country, possibly have better abilities to implement a new nationwide system. In Germany, the political federal structure leads to specific characteristics of the national disaster management system, possibly affecting the implementation of innovations. Austria is also a federalist country but the number of inhabitants constitutes only about one tenth as compared to Germany.

Table 5: Selection criteria (2)-(4) per innovation

Innovation	Timeframe of implementation	Being "new"	Relevance for other organizations
(A) National crisis management system	Initial start 2007, until recently	The national crisis management system is the first IT-based disaster management system that has been used nationwide in the Netherlands.	The relevance for disaster management organizations in the Netherlands is obvious. However, it is also relevant for organizations in other countries that are considering introducing a comparable system.
(B) Staff unit on R&I management within a governmental civil protection agency	Since 2014	The unit presents a structural and highly visible change in the organization. Structural implementation of research had not existed before.	The unit represents an attempt to bridge the gap between research and practitioners, and could concern all practitioner organizations that lack a structural approach to research.
(C) Innovation cluster	Since 2017	There had not been any such network of (including competing) disaster management organizations in Germany before.	Networks can be useful for different types of topics, also depending on other (e.g. societal) developments. It can thus be relevant for any other organization.
(D) Cooperative control center	Different steps since 2001, latest implementation step: 2018, still ongoing	The cooperation between different counties was unique in Germany, and especially the cooperation between rescue services and fire brigade with the police in one building, using the same infrastructure. The new dedicated building and new IT systems are completely new for the control center.	Similar solutions could be implemented for other counties as well, thus relevance for other operational control centers is given.

(E) Compatible disaster management IT system	Since 2007, still ongoing	The disaster management system/situation information system is completely new. There was no IT system for disaster management before.	Relevance for other operational control centers is given, as similar IT solutions could also be implemented in other operational control centers.
(F) Drone	Since 2008, in operational use since 2016	The use of drones to support firefighting is new, the fire brigade considered here is one of the first ones to deploy drones.	This is clearly relevant for other fire brigades or other organizations intending to deploy drones.
(G) Warning system	The warning system was implemented in Austria in 2017	Such a warning system was completely new to Austria. Prior to the introduction of the warning system, the main instrument for public warnings had been sirens.	Many countries do not use warning technology that includes mobile apps. Thus, there is relevance for other organizations and countries.

5.1.3 Selection of experts

For each example innovation, between one and three experts were interviewed, see Table 6. They were selected according to the requirements described in subchapter 3.3.3. All interview partners were heavily involved in the implementation process, in most cases even right from the beginning.

For innovation (A), an employee from the organization that owns the crisis management IT system and provides support to the safety regions in the Netherlands was interviewed. In addition, two representatives of two different safety regions were interviewed. One of them is a user of the system on an operative level, and the other one on a management level.

For innovation (B), the employee that pushed forward the introduction and establishment of the staff unit was interviewed. This person was thus deeply involved in the process from the beginning.

Interview partner for innovation (C) was a representative of the organization that initiated the introduction of the cluster, and who was strongly involved in its establishment.

Interviews on innovation (D) were conducted with a user at management level, and with a representative of the company that provided the IT command system *(Stabs- und Führungssystem)*.

Table 6: Selected experts for interviews

Innovation	Organization type	User/supplier	Acronym[11]
(A) National crisis management system	Organization owning the crisis management IT system	Supplier	A_Su
	Safety region (1)	User (operative level)	A_Us1
	Safety region (2)	User (management level)	A_Us2
(B) Staff unit on R&I management within a governmental civil protection agency	Federal civil protection organization	User (management level) *(+ supplier)*	B_Us
(C) Innovation cluster	Federal civil protection organization	User (management level) *(+ supplier)*	C_Us
(D) Cooperative control center	Cooperative regional control center	User (management level)	D_Us
	Software company offering the IT command system *(Stabs- und Führungssystem)*	Supplier	D_Su
(E) Compatible disaster management IT system	Operational control center	User (operative + management level)	E_Us
(F) Drone	Fire brigade	User and developer	F_Us
(G) Warning system	Ministry	User (operative + management level)	G_Us
	Company supporting the introduction of the warning system	Supplier (+ User (operative + management level))	G_Su

While for innovation (E), a representative of the company that provided the disaster management IT system unfortunately was finally not available for an interview, a user (both at operational and management level) of the system in an operational control center was interviewed.

[11] Acronyms are used for interview references in the following chapters. They indicate the innovation example (A-G), and if the interviewee was a supplier (Su) or user (Us) of the innovation.

The interview partner for innovation (F) was a user of the drone, i.e., owned a drone license. At the same time, the interview partner was also involved in the development of the drone, adapting the functionalities to the fire brigade's needs.

For solution (G), a representative of the company that supports the introduction of the warning system as well as a representative of the responsible ministry in Austria were interviewed. The ministry coordinated the introduction of the warning system and also uses it to send out warnings.

These experts were interviewed according to the methodology as described in subchapter 3.3.4, using an interview guideline (see Annex), during September 2018 – August 2019. In the following subchapter 5.2 the process of evaluating the interview results is described.

5.2 Process description: evaluation of interview results

According to the evaluation process as described in subchapter 3.3.5, the interview transcripts were evaluated as follows:

1) The determinants as derived from the literature-based analysis present a first set of categories, which were defined in the MAXQDA project.
2) The interview transcripts were imported to the MAXQDA project. Each text section of the transcripts in which a predefined determinant is addressed, was assigned to the respective category. (A text section can be assigned to more than one category, if applicable.) Where additional aspects were addressed, new categories were defined.
3) After finishing coding a transcript, the overall category system was revised, the new categories were adapted if needed, and the text and assigned categories were checked once more.
4) This check also included a check of the level of abstraction, aiming at similar levels of abstraction among the categories, and an appropriate total number of categories. The categories defined according to the predefined determinants from the literature-based analysis were complemented by additional categories, representing additional aspects, i.e. a basis for possible new determinants. In addition, a few categories address aspects other than determinants (e.g. general description of the innovation; or proposed measures to enhance future innovation implementation processes).
5) The categories were structured along "sets" in MAXQDA. Most of these sets correspond to the main categories as defined during the literature-based analysis (i.e. "information sharing", "cooperation & knowledge sharing", etc.). Additional "sets" were defined for "additional aspects/new determinants", and "others".

In order to ensure the high quality of the evaluation process, the semantic validity, sampling validity, correlational validity, and intra-coder agreement, as described in subchapter 3.3.6., were checked. The results are as follows:

- **Semantic validity:** Checks were carried out as to whether the defined categories are appropriate by collecting all text passages of the transcribed interviews that were assigned to a specific category. A respective command in MAXQDA was used for the collection. Then, these text passages were assessed regarding homogeneity, and checked against the whole set of defined categories/set of determinants. For the predefined determinants, this procedure especially assured that the determinants are understood in the same way throughout the examples. Accordingly, the assignment of text passages to categories was adapted if needed. For the additional aspects identified, this procedure supports the decision as to whether a new determinant is appropriate; and also the actual definition of a new determinant. Additional smaller aspects that were identified in one case only, with only little influence on the implementation process, were not transferred to a new determinant. However, some similar aspects identified in several examples were transferred to new determinants.
- **Sampling validity:** In order to check if the sampling was accurate, it was investigated as to how the selection criteria for innovations and experts as explained in subchapters 3.3.2 and 3.3.3 are fulfilled. Following subchapter 5.1.2, which explains how the criteria for the selection of innovations are fulfilled and subchapter 5.1.3, which explains how the criteria for the selection of experts are fulfilled, the sampling is considered to be valid.
- **Correlational validity:** As explained in subchapter 3.3.6, usually the results are compared to results achieved using other methods in order to show the correlational validity. In this case, the only apparent possibility is to compare the results to the results of the literature-based analysis – which is an essential part of the study's methodology. Possible deviations between the results of the literature-based analysis and the expert interviews are carefully assessed and evaluated, and explained in chapter 6.
- **Stability – intra-coder agreement:** As described under 3) above, the text and assigned categories were checked once more after the overall category system had been revised, and the new categories were adapted if needed. Only smaller adaptations were required, and a final revision did not reveal any need for additional adaptions.

Thus, it can be summarized that the chosen evaluation methodology adequately meets the quality criteria.

In the following subchapters 5.3 to 5.9, the results are presented per innovation example. In each subchapter, the relevance of the predefined determinant for the implementation process of the innovation is described, based on the expert interviews. The descriptions are presented in tables – one for laws and policies, and one for organizational determinants. Following that, additional identified aspects are described that may possibly form new determinants. The description of each determinant is accompanied by a judgment on the strength of influence of the determinants for the specific innovation implementation process: "Low", if some influence can be identified, "Medium", if the determinant was very relevant for the process, and "High"

for those determinants that constituted the most decisive factors in the process. This assessment is based on explanations by the interviewees, especially in the context of answers to the interview question *"Summarizing the different influencing factors, how strong was the influence of each factor, from your point of view?"* A "+" or "-", in the column "Influence", also indicates if the determinant predominantly supported (+) or hindered (-) the implementation process.

5.3 Innovation A: National crisis management system

5.3.1 Description of the innovation example

The national crisis management system considered here is "a nation-wide crisis management system used in the Netherlands to maintain and share a common operational picture supporting large-scale crisis management collaboration" (Instituut Fysieke Veiligheid 2019, para.1). It is a web-based tool that can be used to share information both within an organization and between different organizations. The system supports a specific way of working – the so called net-centric collaboration, which is "a way of working in which clear agreements are made about sharing information so that decision-making under (crisis) circumstances is always based on an up-to-date, consistent and common operational picture" (ibid.). The system is used by all of the 25 safety regions in the Netherlands[12], several water boards, and some additional organizations (interview A_Su 2018). In the net-centric approach, information is used that has been received from various sources, including TV, radio and internet, and also Twitter, YouTube, etc. (Sophronides et al. 2016; Wilson and Peters 2012). Information can be exchanged in text format as well as in map format, providing support for decisionmakers (Sophronides et al. 2016). The introduction of the national crisis management system started with an "experimentation phase" in 2007 – 2009, involving seven of the 25 safety regions, followed by an implementation project in the years 2009 – 2012, where all of the 25 safety regions implemented the system. The implementation process and its velocity differed among the safety regions and was ongoing in the following years (interview A_Su 2018).

5.3.2 Supporting and hindering determinants

The most relevant determinants as identified through a total of three interviews – one with a representative of the supplier organization, one with a representative of a user organization (safety region (1)) at operative level, and one with a representative of a user organization (safety region (2)) at management level – are described below.

Table 7 presents the determinants in the fields of laws and policies that have been identified through the literature-based analysis (subchapter 4.3.1), and how – based on the expert interviews – these determinants were relevant for the implementation of innovation (A) "National crisis management system".

[12] The safety regions in the Netherlands bring fire services, emergency medical assistance and crisis management under one regional administrative authority (see Dutch Ministry of Security and Justice 2013.).

Table 7: Determinants innovation (A) – laws and policies

Determinant	Influence*	Description
Information sharing		
Privacy and data protection regulations	Low (-)	Privacy and data protection issues arise when collaborating with the police, and in the context of emergency medical care regarding the sharing of medical information. However, this is considered to be manageable. It is also considered to be more of an awareness issue, since crisis communication does not require sharing privacy data (interview A_Su 2018).
Regulation on security of operational data	Medium (-)	Organizations dealing with security-sensitive data are reluctant to share information and thus to use the crisis management system. This especially concerns the police, but also the intelligence agency, which is a collaboration partner in terror cases (interview A_Us1 2018, interview A_Us2 2018). This led to the introduction of a second version of the system on national level, on the occasion of the Nuclear Security Summit that was held in 2014 in The Hague. Only 2-3 people in a safety region had access. This second system is considered to be usable on future occasions as well (interview A_Us2 2018). In addition to security reasons, there can also be commercial reasons for being reluctant to share data. This refers, for example, to harbor companies that are not willing to share information about incoming and outgoing/dispatched goods. One interviewee however mentioned that a reduction of available information could also be positive, since this would reduce the challenge of information overload (interview A_Us1 2018).
Freedom of information legislation	Low-medium (-)	In the Netherlands, the right to information is set out in the Constitution and the Government Information (Public Access) Act (Dutch Ministry of General Affairs 2019). Based on this act, the public, including the media or inspectors, can access the data stored in the crisis management system. There are decisionmakers who are afraid that if something goes wrong, the data could be used e.g. to prosecute people who made incorrect decisions as part of a disaster response (interview A_Us2 2018).

Cooperation & knowledge sharing		
Regulation on protection of intellectual property rights	n/a	n/a
Existence and use of standards	Medium (-)	Before the introduction of the new system, the different safety regions had used different systems with different data formats. It was not possible to integrate all these formats in the crisis management system, which led to struggles before all safety regions finally accepted the system (interview A_Us2 2018).
Protection of employees & of the organization		
Employment protection legislation	n/a	n/a
Liability regulation	Low-medium (-)	See *Freedom of information law*
External incentives		
Available financial resources	**High (-)**	The system's implementation project was financed by the Dutch Ministry of Justice and Safety. The operational phase, further development and maintenance of the system however, has been funded by the safety regions. Each region pays 15 cent per inhabitant per year for the systems' maintenance (interview A_Su 2018). Budget constraints especially to cover the high license costs that each safety region has to pay every year have been an issue for several safety regions. The safety region that includes the national airport Schiphol received the required budget from national government, but for some other regions, this has been a problem for several years. It was also one of the reasons that, in the beginning, not all safety regions wanted to join (interview A_Us2 2018).
General political interest	**High (+)**	See *Legislation requesting assessments of/measures to increase resilience*
Legislation requesting assessments of/measures to increase resilience	**High (+)**	The Dutch Safety Regions Act is the basis of the safety regions, aiming to efficiently organize high-quality fire services, medical assistance and crisis management under one regional management institution (Dutch Ministry of Security and Justice 2013). It encompasses requirements for information management, i.e., the safety regions were obliged to invest in information management. This is considered to have played an important role for the

		introduction of the national crisis management system (interview A_Su 2018).

*Influence of a determinant considered none/not identified (n/a), low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

Table 8 presents the organizational determinants that have been identified through the literature-based analysis (subchapter 4.3.2), and how – based on the expert interviews – these determinants were relevant for the implementation of innovation A, National crisis management system.

Table 8: Determinants innovation (A) – organizational factors

Determinant	Influence*	Description
Staff and work process		
Commitment of individuals	**High (+)**	Support and commitment from higher management level was required, because the introduction of the national crisis management system entailed a serious change process. There was some resistance at lower levels that needed to be overcome (interview A_Su 2018). The passion of involved persons, especially motivation of those who implemented the system and who work with the system was crucial. The motivation to keep going despite bureaucracy etc. was decisive (interview A_Us1 2018). The motivation of the management level was relevant for making financial resources available (interview A_Us1 2018), for giving priority, building a sense of urgency, and for convincing partners (interview A_Us2 2018).
Dedicated unit in the organization	n/a	n/a
Bureaucracy	Low-medium (-)	The interviewees see bureaucracy as a general hindering factor, not only in the case of the national crisis management system. However, in the case of the system, many organizations were involved, which means that requested changes usually took time and a lot of effort (interview A_Su 2018, interview A_Us1 2018, interview A_Us2 2018).
Intra- and interorganizational cooperation and communication		
Internal communication	n/a	Communication issues within a specific organization were not mentioned.
Consideration of employees' wishes and concerns	Medium (+)	Employees have been involved, but actually only after a learning process during the project – specific questions to relevant employees (which information is needed to make a decision) were only raised after the tool had been developed, so

		that several aspects had to be changed (interview A_Us2 2018). Now, even though the possibility exists to request changes to the system, the large amount of organizations involved hampers or slows down the process (interview A_Us2 2018).
Interorganizational cooperation	Medium (+)	Change in the cooperation between organizations has been part of the innovation implementation process. Through exercises, meetings, etc. getting people familiar with each other has been directly targeted. For the national crisis management system to work properly, it is important to know "whom to call for what question" (interview A_Su 2018). It has been found that the cooperation between the safety regions has strongly improved by using the system, since it directly aims at better collaboration, and also an exchange of employees has become easier, since they are trained in the same way (interview A_Su 2018). Organizational differences, however, did not play a role here: The organizational structure is defined in the Safety Regions Act, so the structure is principally uniform (interview A_Su 2018).
Exchanging experiences with similar actors	n/a	No comparable system existed so far (interview A_Su 2018).
Trust	Medium (+)	The improved collaboration as explained under *Interorganizational cooperation* was also about creating trust, which has an important role in interorganizational collaboration (interview A_Su 2018).
Innovation culture		
Openness towards innovations and change	Low (+)	In principle, a quite open innovation culture seems to exist. However, the effect on the national crisis management system implementation is viewed to have played only a minor role in the overall process (interview A_Us1 2018, interview A_Us2 2018).
Incentives for staff; possibility for experimentation	Low (+)	Specific incentives have not been identified, but possibilities for experimentation exist (at least to some extent). However, the effect on the national crisis management system implementation seems to have played only a minor role in the overall process (interview A_Us1 2018, interview A_Us2 2018).

Compatibility of innovation-specific characteristics		
Visibility of the innovation's benefits	**High (+)**	Prior to the introduction of the system, the different disaster management organizations – fire brigade, police, medical service, and also the 25 safety regions – noticed that they did much their own thing, instead of working closer together (interview A_Us1 2018). It has been estimated that, until then, the crisis teams had to base their decisions on information that was already about 30 minutes old. A strong need for more up-to-date information was felt (interview A_Us2 2018). One of the final triggers for the national crisis management system was a fire on New Year's Eve 2000/2001 at a local bar in the Dutch city Volendam, where several people died, and many more were injured. A lesson learned from this disaster was that a solution is needed to enable better information sharing, so that decisions can be based on knowledge about what is actually happening (interview A_Us1 2018). However, it was also mentioned that the fact that there were not many incidents prolonged the process of the innovation implementation because convincing arguments based on real events – and thus the necessary "sense of urgency" – were missing (interview A_Us2 2018). Another event that pushed forward the introduction of the national crisis management system was the Nuclear Security Summit in 2014 in The Hague. This was a "change moment", i.e., with this event, it was able to show that the information process and the tool are needed, and that the partners need and want the tool (interview A_Us2 2018). In addition, during the response to the disaster at Schiphol airport in 2009, where an airplane crashed at landing, and nine people died, the national crisis management system was used, but it did not yet work well. As a consequence, in the evaluation process, the responsible mayor stated that the system is really required and the appropriate budget should be made available to make it work properly (interview A_Us2 2018). Not everything was visible to everybody, since it is tough to communicate the advantages (interview A_Us1 2018). However, employees working with the system have been asked to be "ambassadors"

		for the system, which takes time, but has an impact on the system's success (interview A_Us2 2018).
Integration in daily work	Low (+)	In order to make the system usable during non-crisis times as well, information such as risks, or maintenance plans have also been included (interview A_Su 2018). However, according to another statement, the system is only used in times of crisis. Training courses have been conducted to ensure it works in times of crises (interview A_Us2 2018).
Easy to use	Low (+)	A system that is easily understandable for everybody had been a criterion for the development of the system. In the end, the actual use of the IT system is indeed easy, however, proper use requires qualified personnel and proper training (interview A_Us1 2018) (see *Required knowledge and training*).
Costs	**High (-)**	See also *Available financial resources*. The license costs about 180,000 € per year for each region, which was a challenge for several safety regions at the beginning of the process (interview A_Us2 2018).
Required knowledge and training	Medium (+)	There are training courses for all people who use the system. For the information managers, who require appropriate knowledge most essentially, there are now national norms that make it obligatory for each information manager to complete the training, which takes eight days plus an exam (interview A_Su 2018, interview A_Us1 2018, interview A_Us2 2018).
Required complementary technology/solutions	Medium (+)	In technical terms, the implementation is very easy, since it is web-based (interview A_Su 2018, interview A_Us2 2018).

*Influence of a determinant considered none/not identified (n/a), low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

In addition to the predefined determinants, further aspects (possible new determinants) have been identified that were relevant for the implementation of innovation (A) "National crisis management system", which are presented in Table 9.

Table 9: Additional aspects relevant for the implementation of innovation (A)

Aspect/Possible new determinant	Influence*	Description
Laws, policies		
(None)		
Organizational factors		

Time	**High (+)**	The implementation process took many years, which was also due to the fact that 25 different safety regions, the national, and regional levels were involved. "Time" is also related to the aspects of *Visibility of the innovation's benefits*, which can be more obvious when an event occurs, i.e. the required time can also depend on events pushing forward the innovation. Providing sufficient time for the implementation of the national crisis management system and related working procedures allowed for continuous learning and ensured possibilities for improvement (interview A_Su 2018, interview A_Us2 2018). This also included the opportunity for "learning by doing", i.e., to just start by trying out, instead of long training courses (interview A_Us1 2018). The aspect of time and the possibility for improvement processes was mentioned several times by the interviewees, and was even called "one of the secrets" of the successful implementation of this innovation (interview A_Su 2018).
Required qualified personnel	Medium (-)	The successful use of the national crisis management system heavily depends on the information managers, who collect the information to be fed into the system, and who decide about the relevance of information. Thus, the competence of the information managers is of utmost importance. The implementation process therefore also included an appropriate recruitment and training process (interview A_Su 2018, interview A_Us2 2018). However, finding capable employees is considered to be challenging, and in a few cases, it has even been impossible to find suitable information managers, according to one interviewee (interview A_Us2 2018).
Dependency on a company that is not in the market	Low (-)	One of the interviewees mentioned another issue that could be problematic: The national crisis management system is managed by a company that only takes care of this system, and is thus not part of the market. Not participating in the market means fewer incentives to stay up to date, which can be challenging in the very quickly developing IT domain. For example, it would be desirable to be able to connect the system to the existing systems of additional candidates (e.g. critical infrastructure operators). This would require further developments of the system, which has not happened so far, according to one user interview (interview A_Us2 2018).

Need to give up own solutions; decreasing influence on lower level when using a joint solution	Medium (-)	Another issue has been the fact that a nationwide system replaced several different systems used on a regional level. This means that organizations had to give up their own systems which they were used to and possibly proud of. The system is used in so many organizations, including at different levels, that it is not always possible to implement individual requests. In this sense, innovation was easier before, when it took place only on regional level, within their own system (interview A_Su 2018, interview A_Us1 2018, interview A_Us2 2018).

*Influence of an aspect considered low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

The results of the expert interviews regarding innovation (A) "National crisis management system" as presented in the three tables of this subchapter feed into chapter 6, in which the results of the expert interviews concerning all innovation examples are compared and evaluated.

5.4 Innovation B: Staff unit on Research and Innovation management

5.4.1 Description of the innovation example

Within the governmental civil protection agency considered here, a specific unit dedicated to Research and Innovation (R&I) management has been established, aiming to strategically organize and conduct the agency's research activities. While such a unit might be common for many types of organizations, it is special and innovative for this specific type of organization, because here operative actions are the focus, and there is neither a mandate nor dedicated budget for research in the agency. However, the acknowledged need for research and a rising number of requests to the agency to participate in research projects that could deliver useful results to enhance its capacities and capabilities, led to the initiative to systematically organize research activities in the agency (from 2014), and to establish a dedicated unit. While the agency had already participated in research projects as an associated partner, useful and realizable results were scarce. A stronger dedication to research and project participations as a full partner enabled the agency to better influence the project in line with its needs and provide useful results and even concrete products (interview B_Us 2018).

In 2015, the unit was established for the first time as part of the agency's "operation" *(Einsatz)* department, and was organized as a project with a duration of three years. At the beginning of 2018, recognizing the relevance for the agency as a whole instead of only for the operational part, the unit was moved and is now organized as a staff unit *(Stabsstelle)* within the management *(Leitungsstab)*, directly subordinate to the president of the agency. In this way, the possibility to address all the needs of the agency was to be enhanced (interview B_Us 2018). The staff unit is now one of four strategic components: "strategy in operation", "strategy in

operation support", "strategy in honorary posts", and – the biggest one – "research and innovation management".

5.4.2 Supporting and hindering determinants

The most relevant determinants as identified through an interview with the head of research at the agency are described below.

Table 10 presents the determinants in the field of laws and policies that have been identified through the literature-based analysis (subchapter 4.3.1), and how – based on the expert interview – these determinants were relevant for the implementation of innovation (B) "Staff unit on R&I management."

Table 10: Determinants innovation (B) – laws and policies

Determinant	Influence*	Description
Information sharing		
Privacy and data protection regulations	n/a	n/a
Regulation on security of operational data	n/a	n/a
Freedom of information legislation	n/a	n/a
Cooperation & knowledge sharing		
Regulation on protection of intellectual property rights	n/a	n/a
Existence and use of standards	n/a	n/a
Protection of employees & of the organization		
Employment protection legislation	n/a	n/a
Liability regulation	n/a	n/a
External incentives		
Available financial resources	**High (-)**	Since there has been no legal mandate for the agency considered in this case to carry out research, there is also no budget dedicated to research. A lack of budget and personnel is seen as a general constraint, because neither are earmarked for research. Thus, they have to be taken from other areas. At the time of the interview, only three positions were financed by the agency, the other

		ones had to be financed using third-party funds (interview B_Us 2018).
General political interest	Low (+)	The process was initiated by the agency. However, it was supported by the German Federal Ministry of Education and Research (interview B_Us 2018).
Legislation requesting assessments of/measures to increase resilience	n/a	n/a

*Influence of a determinant considered none/not identified (n/a), low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

Table 11 presents the organizational determinants that have been identified through the literature-based analysis (subchapter 4.3.2), and how – based on the expert interview – these determinants were relevant for the implementation of innovation (B) "Staff unit on R&I management".

Table 11: Determinants innovation (B) – organizational factors

Determinant	Influence*	Description
Staff and work process		
Commitment of individuals	**High (+)**	The head of research at the agency initiated both the initial establishment of the unit "R&I management" and its later integration in the management staff. Additionally, the support of the agency's president was crucial ("since a new process in a federal agency encounters resistance" (interview B_Us 2018)), who was convinced of the benefits of research within the agency. Since the agency is subordinate to the Ministry of the Interior, the decision also very much depended on the respective person in charge of the Ministry. It was not self-evident, since another agency, the Federal Office of Civil Protection and Disaster Assistance (BBK), is in charge of research activities in this field, and the decision could have been to leave any research activities with the BBK. However, the Ministry supported the decision to introduce a research unit within the agency, which was supportive of the process that followed. The interviewee considered the commitment and support of these people to be the most crucial factor (interview B_Us 2018).
Dedicated unit in the organization	n/a	This innovation is exactly about establishing a dedicated unit in the organization.

Bureaucracy	Low (-)	The main obstacles were the lack of a mandate, and thus the missing budget and personnel (interview B_Us 2018). This was further explained and covered by the determinant *Available financial resources*.
Intra- and interorganizational cooperation		
Internal communication	Low (-)	An attempt has been made to communicate and spread the benefits internally. However, the interviewee admitted that this has not happened sufficiently, due to lack of time. The missing communication and required persuasive efforts have been – for example – noted, when colleagues of other departments were asking what the R&I management unit actually did (interview B_Us 2018).
Consideration of employees' wishes and concerns	Medium (-)	Employees have not been involved in the process. Information was communicated, but the higher level has not passed on information sufficiently. This led to some protest and anxieties among the employees (interview B_Us 2018).
Interorganizational cooperation	n/a	n/a
Exchanging experiences with similar actors	Low (-)	Especially in the beginning, exchanging experiences was not possible at all. There were good contacts to two related organizations with own research departments. One of these has been considered to have stronger feelings of competition, while the exchange with the other one was more open. Here, personal contacts and trust have been considered to be the decisive factors (interview B_Us 2018).
Trust	**High (+)**	Trust is considered to play a very significant role in the process (interview B_Us 2018).
Innovation culture		
Openness towards innovations and change	**High (-)**	The interviewee sees a "natural hostility to innovation" at the agency, mainly based on the human fear of change. There are a few examples, especially among the voluntary employees, where employees are motivated to innovate. However, implementation processes take a lot of time. In this specific case, resistance to change also played a role, because employees were afraid of losing something through the process (interview B_Us 2018).
Incentives for staff; possibility for experimentation	Low-medium (-)	No specific incentives seem to exist. There is a budget line for trial periods at the agency. However, there are a lot of formalities to making a

		request, and it is only applicable to specific measures. The process of introducing new technology to the equipment list (which is the basis for any procurement) is very complex (interview B_Us 2018).
Compatibility of innovation-specific characteristics		
Visibility of the innovation's benefits	Medium (-)	See *Internal communication*: There have been attempts to communicate and spread the benefits internally. However, the interviewee admits that this has not happened sufficiently, due to a lack of time. The missing communication and required persuasive effort is for example noted when colleagues from other departments ask what is actually done in the R&I management unit. Since information has not been passed on adequately, the benefits were not sufficiently visible for the employees. (interview B_Us 2018).
Integration in daily work	n/a	n/a
Easy to use	n/a	n/a
Costs	n/a	The "costs" for this innovation are very much related to the general issue that there is no budget dedicated to research. See *Available financial resources*.
Required knowledge and training	n/a	n/a
Required complementary technology/solutions	n/a	n/a

*Influence of a determinant considered none/not identified (n/a), low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

In addition to the predefined determinants, further aspects (possible new determinants) have been identified that were relevant for the implementation of innovation (B) "Staff unit on R&I management", which are presented in Table 12.

Table 12: Additional aspects relevant for the implementation of innovation (B)

Aspect/Possible new determinant	Influence*	Description
Laws, policies		
(None)		
Organizational factors		
Personal contacts	**High (+)**	Personal contacts played a decisive role in this implementation process, following the interviewee (interview B_Us 2018).

Time for learning	**High (+)**	In order to start the work on R&I management effectively, learning processes were important. This included gaining knowledge on how to successfully design and conduct projects, as well as getting to know relevant people in the research domain. This process took about two years (interview B_Us 2018).

*Influence of an aspect considered low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

The results of the expert interview regarding innovation (B) "Staff unit on R&I management" as presented in the three tables of this subchapter feed into chapter 6, in which the results of the expert interviews concerning all innovation examples are compared and evaluated.

5.5 Innovation C: Innovation cluster

5.5.1 Description of the innovation example

For the field of innovation in disaster and civil protection in Germany, a cluster of agencies and organizations with security tasks, as well as related research organizations, has been established. It aims to identify, enhance, and streamline potential innovation activities. Establishing the cluster was an initiative of the governmental civil protection agency considered in innovation (B). When starting to carry out research at the agency, it became clear that a stronger network of practitioners is needed. Before establishing the cluster, informal meetings with different practitioners in so-called fireplace chats *(Kaminrunden)* were conducted. However, after a while the fireplace chat participants noticed that external input would be highly useful, thus, the cluster now involves additional and other types of organizations and is also more visible for the federal government. In contrast to the fireplace chats, the innovation cluster involves research organizations as well as additional practitioners and pertinent federal agencies. The cluster is much better at enabling joint agreements, the possibility to formulate needs, and the ability to receive more global input (interview C_Us 2018).

5.5.2 Supporting and hindering determinants

The most relevant determinants as identified through an interview with a representative of the governmental civil protection agency, who initiated the cluster, are described below.

Table 13 presents the determinants in the field of laws and policies that have been identified through the literature-based analysis (subchapter 4.3.1), and how – based on the expert interview – these determinants were relevant for the implementation of innovation (C) "Innovation cluster".

Table 13: Determinants innovation (C) – laws and policies

Determinant	Influence*	Description
Information sharing		
Privacy and data protection regulations	n/a	n/a
Regulation on security of operational data	n/a	n/a
Freedom of information legislation	n/a	n/a
Cooperation & knowledge sharing		
Regulation on protection of intellectual property rights	n/a	n/a
Existence and use of standards	n/a	n/a
Protection of employees & of the organization		
Employment protection legislation	n/a	n/a
Liability regulation	n/a	n/a
External incentives		
Available financial resources	Low (-)	At least starting the cluster did not cause any budget issues, since there were barely any costs except for those related to meetings. Each organization pays its own travel costs. Thus, interest in the initiative was sufficient to cover the required costs (interview C_Us 2018). However, to move forward, to make best use of the cluster, funding is required. Respective initiatives are currently ongoing, trying to acquire budget for joint work in the cluster. An ideal version would be an equivalent to the SAFEcluster[13] in France, which has its own resources. This would also enable collaboration on EU level (interview C_Us 2018).
General political interest	n/a	Political interest did not play a role here (interview C_Us 2018).
Legislation requesting assessments	n/a	There was no respective legislation (interview C_Us 2018).

[13] The SAFEcluster is a network of customers and suppliers of security solutions in France, see http://www.safecluster.com (checked on 14/11/2019)

of/measures to increase resilience		

*Influence of a determinant considered none/not identified (n/a), low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

Table 14 presents the organizational determinants that have been identified through the literature-based analysis (subchapter 4.3.2), and how – based on the expert interview – these determinants were relevant for the implementation of innovation (C) "Innovation cluster".

Table 14: Determinants innovation (C) – organizational factors

Determinant	Influence*	Description
Staff and work process		
Commitment of individuals	**High (+)**	The interview partner initiated the cluster. He conducted several bilateral conversations with envisaged partners of the cluster (interview C_Us 2018).
Dedicated unit in the organization	Low (+)	Even though it was not mentioned in the interview, it was probably useful that R&I activities are concentrated in a dedicated unit at the organization that initiated the cluster.
Bureaucracy	n/a	n/a
Intra- and interorganizational cooperation		
Internal communication	n/a	n/a
Consideration of employees' wishes and concerns	n/a	n/a
Interorganizational cooperation	Medium (-)	According to the interview partner, there has been a lack of communication among organizations of the same type, also due to aspects of competition. In this respect, this governmental civil protection agency is a neutral partner and was thus able to initiate such a network (interview C_Us 2018). Regarding organizational differences, there are indeed structural differences among the organizations; however, this was not an obstacle. The interview partner was used to these differences, based on mission experience (interview C_Us 2018).
Exchanging experiences with similar actors	n/a	There has not been such a network before. Fire brigade networks have existed before, such as the working group of leaders of professional fire brigades[14], or the German Fire Protection

[14] In German „Arbeitsgemeinschaft der Leiter der Berufsfeuerwehren – AGBF"

		Association[15]. However, a network of all these different types of actors did not exist in Germany before (interview C_Us 2018).
Trust	**High (+)**	Trust was a crucial requirement for establishing the cluster. The non-binding character of the initial meetings was important especially for these types of users, i.e., there was no agenda or records of the talks. This enabled participants to talk about issues that they would possibly not mention in an official context. It was only due to the personal nature of the contacts that this kind of trust could be built up (interview C_Us 2018).
Innovation culture		
Openness towards innovations and change	n/a	n/a
Incentives for staff; possibility for experimentation	n/a	n/a
Compatibility of innovation-specific characteristics		
Visibility of the innovation's benefits	Medium - High (+)	When starting with research, it soon became clear that a stronger network is required. Disaster management organizations had often been asked to join a project consortium, while no joint strategy existed for doing so (interview C_Us 2018).
Integration in daily work	n/a	n/a
Easy to use	n/a	n/a
Costs	n/a	Direct costs for implementing the innovation were only related to costs for travelling to meetings. (See also *Available financial resources*).
Required knowledge and training	n/a	n/a
Required complementary technology/solutions	n/a	n/a

*Influence of a determinant considered none/not identified (n/a), low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

In addition to the predefined determinants, further aspects (possible new determinants) have been identified that were relevant for the implementation of innovation (C) "Innovation cluster", which are presented in Table 15.

[15] In German „Vereinigung zur Förderung des Deutschen Brandschutzes e.V. – vfdb"

Table 15: Additional aspects relevant for the implementation of innovation (C)

Aspect/Possible new determinant	Influence*	Description
Laws, policies		
(None)		
Organizational factors		
Personal contacts	**High (+)**	Establishing the cluster required a considerable level of trust (see above), which could only be achieved through personal contacts. Only the personal network of the initiator made it possible to gain the necessary trust of representatives from the partner organizations (interview C_Us 2018).

*Influence of an aspect considered low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

The results of the expert interview regarding innovation (C) "Innovation cluster" as presented in the three tables of this subchapter feed into chapter 6, in which the results of the expert interviews concerning all innovation examples are compared and evaluated.

5.6 Innovation D: Cooperative control center

5.6.1 Description of the innovation example

The cooperative regional control center *(Kooperative Regionalleitstelle)* in Germany considered here has developed in several innovative steps. The first innovative step was in 2001, when three counties *(Landkreise)* jointly started to operate one common cooperative control center, including fire brigade and rescue services. Usually, a county or city operates its own control center; it was the first time in Germany that three counties had operated one control center together. From 2006, discussions started on operating the control center together with the police as well, which is the responsibility of the states *(Bundesländer)*. This was implemented in 2010, when rescue services, fire brigade and police started to work in the same building using the same infrastructure and technology, while clearly keeping the work separate. The most recent innovative step was taken in 2018, when the joint cooperative control center, with rescue services, fire brigade, and police, moved into a new dedicated building specifically designed for the center's purposes. This included new network technology, but also attractive working places (interview D_Us 2018).

On the one hand, the new compatible IT systems comprise communication technology, media technology, and the control center system *(Leitstellensystem)* (for emergencies), provided by one company. On the other hand, the command system *(Stabs- und Führungssystem)* (for disaster events), provided by another company, was implemented in parallel. In disaster events, disaster task forces *(Katastrophenstäbe)* are responsible, so it needs to be ensured that relevant information is transferred from the control center to the disaster task force – via the command system (interview D_Us 2018).

The common IT system required specific security measures to make it usable for the police as well, resulting in additional efforts being required to coordinate the needs of all actors involved (interview D_Su 2019). The software was implemented in the control center, but also in the related counties and their fire brigades. While a temporary version of the new joint IT network is already running, the implementation process is actually still ongoing, and the final version is not yet running (at the time of the second interview, i.e. January 2019) (interview D_Su 2019).

5.6.2 Supporting and hindering determinants

The most relevant determinants as identified by means of two interviews, one with a user (management level), and one with the supplier of the command system *(Stabs- und Führungssystem),* are described in the following.

Table 16 presents the determinants in the field of laws and policies that have been identified through the literature-based analysis (subchapter 4.3.1), and how – based on the expert interviews – these determinants were relevant for the implementation of innovation (D) "Cooperative control center".

Table 16: Determinants innovation (D) – laws and policies

Determinant	Influence*	Description
Information sharing		
Privacy and data protection regulations	Low (-)	In general, there are data protection issues in the medical field. For example, when introducing a mobile app to alarm first aiders that are close to an incident, the app requires the actual location of the first aiders. However, this was solved (interview D_Us 2018). The new command system does not receive any patient data. As an exception, in case of mass casualty incidents, anonymized data on severely injured persons is transferred, to allow them to receive medical treatment first (interview D_Su 2019).
Regulation on security of operational data	**High (-)**	Additional security requirements complicated the introduction of the compatible control center system *(Leitstellensystem)* and the command system: It needed to be assured that the interface of the two systems does not cause a crash or unintended release of information. This is especially relevant as police and disaster response organizations work in one system. For example, police files must not be transferred to fire brigades. While this was solved technically, some people still had concerns. Due to these concerns, it will not be possible to access the control center system via the command system, even though it would technically be possible.

		Instead, there will only be a mirror version (interview D_Su 2019). In this context, the hurdle of security for operational data can be understood as doubts concerning the ability of technology to assure the required security. According to the supplier's perspective, this issue has caused the biggest part of the requirements, and the strongest need for coordination (interview D_Su 2019).
Freedom of information legislation	n/a	n/a
Cooperation & knowledge sharing		
Regulation on protection of intellectual property rights	n/a	n/a
Existence and use of standards	**High (-)**	Due to the heterogeneous system of control centers, both user and supplier see a need for standardization (interview D_Us 2018, interview D_Su 2019). The lack of standards seems to absorb additional efforts and resources. In response to that, an association of control centers, established to address the politically caused heterogeneity, has initiated a standard plan for control center rooms. In addition, a standard list of specifications for control centers could possibly facilitate the situation (interview D_Us 2018). Something like a "quasi standard" is already created when consultants are tasked with procurement, and use similar texts for different customers (interview D_Us 2018). Existing standards comprise visual presentation in a collaboration software, such as symbols on a map (e.g. a fire, or an injured person) (interview D_Su 2019). Other standards include the organization of staff unit work *(Stabsarbeit)*, for example, organizing which functions have to be covered. These standards exist on state level in Germany. Most of them are similar, but there are also deviations, e.g. in the state of Bavaria. The standards also define the names for staff unit. For example, in many states there is one staff unit for the operative and tactical part *(Führungsstab)*, and one staff unit for the administrative and organizational part *(Verwaltungsstab/Krisenstab)*. In Bavaria, there is only one joint staff unit. Another

		one *(Stab für außergewöhnliche Ereignisse)* exists for example in the state of Thuringia, which has a mixed format. According to the solution supplier, when the required knowledge is available it is possible to adapt software relatively easily to these different conditions (interview D_Su 2019). Both supplier and user see the possibility of improving the situation by having stronger standardization in the areas of procurement, and regulations on disaster management that are very heterogeneous due to the political federal structure (interview D_Us 2018, interview D_Su 2019).
Protection of employees & of the organization		
Employment protection legislation	n/a	n/a
Liability regulation	n/a	n/a
External incentives		
Available financial resources	Low (-)	Financing is seen as an issue, but usually not as a problematic one. A financial hurdle that control centers for rescue services often face is the following: The main organization financing the control centers for rescue services in Germany are the health insurance associations. These associations are bound to the efficiency principle (§ 12 Abs.1 SGB V), which means that only those costs can be covered that are "necessary", "appropriate", and "efficient". Since proving efficiency in emergency management is difficult, or is sometimes only possible at a later stage, the efficiency principle can question any innovative idea. (As soon as it is purely about disaster management, in contrast to daily emergency management, insurance associations are not in charge.) The construction of the new joint building was only possible because argumentations based on the efficiency principle were limited by building regulations (interview D_Us 2018). Convincing decisionmakers on a political/county level, however, is usually not problematic, according to the experience of the interviewed user, since awareness and engagement is sufficiently given (interview D_Us 2018).
General political interest	n/a	n/a
Legislation requesting	n/a	n/a

assessments of/measures to increase resilience		

*Influence of a determinant considered none/not identified (n/a), low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

Table 17 presents the organizational determinants that have been identified through the literature-based analysis (subchapter 4.3.2), and how – based on the expert interviews – these determinants were relevant for the implementation of innovation (D) "Cooperative control center".

Table 17: Determinants innovation (D) – organizational factors

Determinant	Influence*	Description
Staff and work process		
Commitment of individuals	**High (+)**	In general, according to the user's view, the different personalities and level of commitment of those who are responsible for a control center add to the heterogeneous system (see above), since everything beyond the basic functions is very different. Also in this specific case, it was important that it was led by someone with a passion for it. This passion also transferred to other people involved, and thus very much facilitated the implementation process (interview D_Us 2018). The interviewed supplier recognized the engagement and openness of the user in this specific case, too (interview D_Su 2019).
Dedicated unit in the organization	n/a	Employees with the appropriate IT knowledge were required, which was given in the case of the control center considered here (interview D_Su 2019). However, a dedicated unit on research, development, or innovation, does not exist.
Bureaucracy	Low (-)	The interviewees do not see any crucial bureaucratic issues related to this specific process. However, general bureaucracy issues have been mentioned: According to the user, what happens frequently is that a new solution or process is implemented, and respective legislation is adapted afterwards – rather than the other way around (interview D_Us 2018). Another example of bureaucracy is when clients/users have the required financial resources, but then not the necessary personnel to implement a solution. Then the budget needs to be deferred year after year,

		which causes many administrative expenses (interview D_Su 2019).
Intra- and interorganizational cooperation and communication		
Internal communication	n/a	n/a
Consideration of employees' wishes and concerns	**High (+)**	Employees were very much involved in the process. They co-designed the ergonomics and other aspects of the new working places; votes and interviews were conducted. This has been in contrast to the usual procedures, which are rather top-down, and is seen as an important success factor (interview D_Us 2018).
Interorganizational cooperation	**High (+)**	According to the user, there is a tradition of trustful cooperation among the participating organizations (rescue services, fire brigades, and others). In the implementation process, this included a high level of transparency, and the possibility to openly communicate things that went wrong during the implementation process. This has been seen as a success factor. The close cooperation structure is now even more enhanced through the jointly used building, which, for example, also includes a joint communication zone (interview D_Us 2018).
Exchanging experiences with similar actors	Low (+)	There was no specific similar case to learn from. In general, however, according to the user, a strong network is very helpful, also for the reasons explained above (heterogeneous structure). Regarding possible improvements in future innovation implementation processes, the interviewee mentioned best practice models, among other things. An orientation to existing systems could be helpful. An example is the standard plan for control center rooms as mentioned above (interview D_Us 2018).
Trust	Medium (+)	Trust has been relevant in the context of the possibility to be honest, admit mistakes and communicate things that go wrong (interview D_Us 2018).
Innovation culture		
Openness towards innovations and change	Medium (+)	Both interview partners confirmed that openness towards innovations is very different among the different users (interview D_Us 2018, interview D_Su 2019). In this case, the supplier also recognized the high level of openness at the control center. For example, the new software was already

		being used before the first training courses (interview D_Su 2019). Usually, when there is a call for tender, openness in the organization is already there. However, the supplier sometimes also notices persons being rather resistant to change. He recognizes a tendency that younger people are often more open towards the IT solutions, while older ones sometimes prefer the analogue procedures. However, it very much depends on the individual personalities, and the complete opposite was experienced, too (interview D_Su 2019).
Incentives for staff; possibility for experimentation	**High (+)**	The interviewed user has highlighted the importance of transparency, tolerance to delays instead of strict deadlines in order to encourage communication about problems, and to allow for mistakes. Even though there is room for improvement, these principles were realized to a great extent, which is seen as a crucial success factor (interview D_Us 2018).
Compatibility of innovation-specific characteristics		
Visibility of the innovation's benefits	Low (+)	For general awareness, a visible threat situation can be helpful. In the course of this specific innovation implementation, ongoing communication was part of the overall process. However, the people involved were sufficiently aware (interview D_Us 2018).
Integration in daily work	Medium (+)	As far as possible, the control center also tries to use the systems in their daily work, i.e., in non-crisis times, for example, by using the same server. Rooms in the new building dedicated to disaster management are used for meetings in non-disaster times (while assuring that they are always ready to be used in case a disaster occurs). In addition, regular training courses are conducted, and each working place in the control center allows access to a training system. However, it has not been possible to use the command system for daily work, since the users are too different (depending on the type of disaster, agencies such as the environment agency can be among the required users of the command system (interview D_Us 2018). According to the supplier, there are counties and fire brigades that use the command system in their daily work. This is possible as the software was designed so that it could be used for recording

		normal missions. While control center software is used in the control center, but not on location, the command system can also be accessed on location, for example for working with checklists (interview D_Su 2019).
Easy to use	Low (+)	When procuring the command system, one of the requirements was that the user interface has to be user-friendly and similar to the regularly used software, e.g. Microsoft Outlook as the mail client.
Costs	n/a	Some general financing issues are described under *Available financial resources*. According to the interviewed supplier, it can happen that only when a project is already up and running does it become clear that additional services are required in order to realize the objectives. These additional costs can cause problems. In this case however, the project was planned very well, and no additional services and related costs were required (interview D_Su 2019).
Required knowledge and training	Low (+)	Training courses were conducted when introducing the product, and to help users familiarize themselves with software updates (interview D_Su 2019).
Required complementary technology/solutions	n/a	The software that was introduced only requires common computer hardware (PCs and notebooks), for software installation and use (interview D_Su 2019).

*Influence of a determinant considered none/not identified (n/a), low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

In addition to the predefined determinants, further aspects (possible new determinants) have been identified that were relevant for the implementation of innovation (D) "Cooperative control center", which are presented in Table 25.

Table 18: Additional aspects relevant for the implementation of innovation (D)

Aspect/Possible new determinant	Influence*	Description
Laws, policies		
Heterogeneous structure due to the federal political system	**High (-)**	In Germany at the moment, there are 243 local control centers, based on control center laws *(Leitstellengesetze)* that differ between the German federal states. In combination with different commitments, attitudes etc. of responsible leaders, the user interviewee points out the large differences between the control centers, apart from the common basic functions that they all fulfill (interview D_Us 2018). This also means that the

		centers' specifications *(Lastenhefte)* are different, and therefore the technical requirements defined in a call for tender, too. This can lead to difficulties for suppliers to adequately meet the demands (interview D_Us 2018; see also "Specific needs, impossible to be addressed by supplier" below). Tender platforms and their requirements are also different, which can lead to challenges for a supplier (interview D_Su 2019; see also "Tendering procedure" below). In addition, it can lead to parallel developments and needless use of resources, because adequate exchange and collaboration is missing. An association of control centers has been established to address these issues of heterogeneity (interview D_Us 2018). The federal structure can also complicate the challenge to bring all required organizations together, and make them use one common system. For example, to make the new command system usable, the county, the communities in the county, their fire brigades, and in this case even the police, which is the responsibility of the federal states, needed to be involved. The supplier of the command system stated that appropriate software solutions do exist to overcome issues related to this; however, the involvement of the police has been a special case (interview D_Su 2019).
Tendering procedure	Medium (-)	The tendering regulations can lead to issues as described above, i.e., it may be impossible for suppliers to fulfill requests from users, at least within a short time frame (see also "Specific needs, impossible to be addressed by supplier" below). The supplier sees hurdles related to the procurement procedures, because there are no uniform regulations. Since there is no standard for tendering platforms, requirements can be challenging for the applicants. For example, the procurement process sometimes requires software to be downloaded that is very much lacking adequate security (which was however not the case in this example) (interview D_Su 2019).
Efficiency principle	Medium (-)	As explained under the determinant *Available financial resources*, control centers for rescue services can suffer due to the efficiency principle (§ 12 Abs.1 SGB V) which health insurance associations have to comply with. They are the main organization financing the control centers for rescue services in Germany, and thus only those costs can be covered that are "necessary", "appropriate", and "efficient". Since

		proving efficiency in emergency management is difficult, or is sometimes only possible at a later stage, the efficiency principle can question any innovative idea. (As soon as it is purely about disaster management, in contrast to daily emergency management, insurance associations are not the ones in charge.) (interview D_Us 2018).
Organizational factors		
Specific needs, impossible to be addressed by supplier	Medium-**High** (-)	The differing specifications for control centers (see "Heterogeneous structure due to the federal political system") entail different solution requests to supplier companies. In combination with the usually desired short delivery timeframes, and the small and specialized market (see subchapter 2.2), this impedes the possibility for suppliers to meet these requests in this form. In addition, according to the interviewed user's point of view, supplier capacities are sometimes blocked because they are busy answering requests from new clients, at the expense of developing demands from existing clients. Thus, innovative ideas sometimes cannot be realized within short time frames, even if resources and technical requirements are available (interview D_Us 2018). The new command system was a crucial further development when compared to the previous system, however, not always to the extent originally desired, e.g., allowing access to new web tools (interview D_Us 2018). From the interviewed supplier's point of view, the software product offered is now mature enough, already covering many needs, to just develop and install a software update in case a tender requests additional functions. According to this interview, existing clients do not have many new ideas/requests, but benefit from the updates that have been developed based on new clients' requests, or from developments of the supplier's own. This is possible now that the software is mature and used by many organizations (interview D_Su 2019). Regarding the construction of the new building including its innovative concepts, issues of individual requests as described have not caused any problems because the construction industry is used to individual constructions, and costs are taken into account respectively (interview D_Us 2018).
Required qualified personnel	Low (+)	The implementation of the new IT system required employees with appropriate IT knowledge to be

		working at the operational control center (interview D_Su 2019).
Time	High (+)	See *Incentives for staff; possibility for experimentation*. While allowing for flexibility regarding deadlines and milestones, the interviewed user also recommends just getting started with the existing possibilities, rather than waiting e.g. for legislation to change (interview D_Us 2018).
Network	Medium (-)	Related to the "heterogeneous structure due to the federal political system", the interviewed user highlighted the importance of networks, such as the association of control centers for rescue services. He would recommend a knowledge database, in order to increase knowledge transfer, and avoid unnecessary separate actions in parallel (interview D_Us 2018).

*Influence of an aspect considered low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

The results of the expert interview regarding innovation (D) "Cooperative control center" as presented in the three tables of this subchapter feed into chapter 6, in which the results of the expert interviews concerning all innovation examples are compared and evaluated.

5.7 Innovation E: Compatible disaster management IT system

5.7.1 Description of the innovation example

Just like the cooperative control center in the previous example, the warning center of a federal state in Austria considered in the following example also operates an operative control center. However, the structure is different. The warning center is the disaster management agency for the specific federal state, and is, amongst others, tasked with the development of disaster management plans, and with operating warning services for storms and avalanches. But the agency also operates an operative control center, and lets out rooms to the Austrian Red Cross, which operates the control center for the rescue services and fire brigades. This concept has existed for 25 years. However, several organizational units related to the warning center have formulated their wish to participate more actively in missions by having access to information from the control center, to be able to see how personnel and material is arranged etc. This led to the decision in 2009, to implement a new operational control center system *(Einsatzleitsystem)*. Complementing this, a new disaster management system *(Lage- und Stabssystem)* was also planned. This disaster management system receives information from different subsystems, the operational control center system being one of them. Another subsystem is a situation information system used by the fire brigades. Information from the operational control center system and the disaster management system is interchangeable. Thus, at the end of a mission, there is one joint mission log. In 2007/2008, an EU wide tender was issued for an operational control center system, but also for a disaster management system. The winner was a company that provided both systems. While an operational control center system had existed before, there was no IT system for disaster management, and

disaster management was conducted completely separately. The use of the new operational control center system started in 2009. Then, the disaster management system and the situation information system were implemented as well. Since then, the overall system is constantly developing; for example, a mobile app was added in 2017 (interview E_Us 2018).

5.7.2 Supporting and hindering determinants

The most relevant determinants as identified through an interview with a representative of the warning center, i.e., a user (management and operational level), are described below.

Table 19 presents the determinants in the field of laws and policies that have been identified through the literature-based analysis (subchapter 4.3.1), and how – based on the expert interview – these determinants were relevant for the implementation of innovation (E) "Compatible disaster management IT system".

Table 19: Determinants innovation (E) – laws and policies

Determinant	Influence*	Description
Information sharing		
Privacy and data protection regulations	n/a	Data protection in Austria was not such a big issue as for example in Germany. With the coming of the GDPR, the topic became more significant, however, this did not cause any problems (interview E_Us 2018).
Regulation on security of operational data	n/a	n/a
Freedom of information legislation	n/a	n/a
Cooperation & knowledge sharing		
Regulation on protection of intellectual property rights	n/a	n/a
Existence and use of standards	n/a	n/a
Protection of employees & of the organization		
Employment protection legislation	n/a	n/a
Liability regulation	n/a	n/a
External incentives		
Available financial resources	Medium (-)	It was a huge effort to gain the required budget, and to conduct the comprehensive procurement process. For this reason, an attempt was made to cover all the main issues in this process, which had come up over the last years. €12 million were

		invested, which is a lot, considering the number of inhabitants in this particular federal state, which is about 380,000. For political reasons, the budget was supposed to be spent within a specific timeframe, i.e., before an election (interview E_Us 2018).
General political interest	n/a	According to the interviewee, political interest is usually not the trigger for innovations here. Initiatives are more often rooted in the operational level, for example at fire brigades and rescue services. Initiatives are discussed in an advisory council of operational control centers *(Leitstellenbeirat)*, where each organization has a voice. From here, suggestions are transferred to the political level. In this case, there was also agreement that the old system was not sufficient anymore, and that action was required to improve the situation (interview E_Us 2018).
Legislation requesting assessments of/measures to increase resilience	n/a	n/a

*Influence of a determinant considered none/not identified (n/a), low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

Table 20 presents the organizational determinants that have been identified through the literature-based analysis (subchapter 4.3.2), and how – based on the expert interviews – these determinants were relevant for the implementation of innovation (E) "Compatible disaster management IT system".

Table 20: Determinants innovation (E) – organizational factors

Determinant	Influence*	Description
Staff and work process		
Commitment of individuals	**High (+)**	According to the interviewee, both on the user's side as well as the supplier's side, many employees showed high personal commitment, contributed their technical knowledge, and did more than would usually have been "necessary". This was crucial for success (interview E_Us 2018).
Dedicated unit in the organization	n/a	n/a
Bureaucracy	n/a	The only hurdle in this sense was rooted in the tendering procedure, which was already a huge challenge (interview E_Us 2018).
Intra- and interorganizational cooperation and communication		

Internal communication	n/a	n/a
Consideration of employees' wishes and concerns	Low (+/-)	There was a project group at a higher level, and several working groups at lower levels. Attempts were made to involve everybody, but some discussions and disagreements could not be avoided (interview E_Us 2018).
Interorganizational cooperation	n/a	The cooperation between the organizations involved improved through the implementation of the new system. However, the collaboration had worked well before, also due to a clear division of labor, which is helpful during missions (interview E_Us 2018).
Exchanging experiences with similar actors	n/a	There was no other previous example to learn from. The interviewee stated that in general, the federal state which runs the warning center is a pioneer in these topics (interview E_Us 2018).
Trust	n/a	n/a
Innovation culture		
Openness towards innovations and change	Low (+)	The openness towards innovation at the warning center is considered to be good (interview E_Us 2018).
Incentives for staff; possibility for experimentation	n/a	n/a
Compatibility of innovation-specific characteristics		
Visibility of the innovation's benefits	n/a	n/a
Integration in daily work	Medium (+)	During the development of the solution, emphasis was put on the possibility of not only being able to use it in times of crisis, but also in non-crisis times. Also, employees of the warning center accompanied and contributed to the implementation process, making sure that the required knowledge was available and enhancing its integration in their daily work (interview E_Us 2018).
Easy to use	Medium (+)	In addition to the integration in daily work, clear emphasis was also put on achieving a solution that is easy to use. This has been especially important, because the system is used by many voluntary employees, who do not work with it on a daily basis. Thus, it needs to be easily usable for everyone, in smaller daily missions as well as in case of a disaster (interview E_Us 2018).

Costs	Medium (-)	The costs of this innovation were quite high, i.e. €12 million (considering that this federal state only has about 380,000 inhabitants). As described under *Available financial resources* it was quite an effort to raise the required budget (interview E_Us 2018).
Required knowledge and training	n/a	n/a
Required complementary technology/solutions	Low (+)	Emphasis was put on having a system that is compatible with the existing ones. There are barely any further requirements for the participating organizations (interview E_Us 2018).

*Influence of a determinant considered none/not identified (n/a), low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

In addition to the predefined determinants, further aspects (possible new determinants) have been identified that were relevant for the implementation of innovation (E) "Compatible disaster management IT system", which are presented in Table 21.

Table 21: Additional aspects relevant for the implementation of innovation (E)

Aspect/Possible new determinant	Influence*	Description
Laws, policies		
Tendering procedure	Medium (-)	Issues with the tendering procedure have already been identified in the previous example. Here too, the tendering procedure and the effort required strongly influenced the process. Due to the vast efforts required for the tendering procedure, attempts were made to cover all the main issues in this process, which had come up over the last few years, in an attempt to avoid another tendering procedure. However, when starting the implementation, it turned out to be impossible to implement everything at once. Thus, the interviewee would have preferred several smaller packages of action, which was impossible, because this would have required another bout of tendering procedures (interview E_Us 2018).
Organizational factors		
Specific needs, impossible to be addressed by supplier	Medium (-)	As in the previous example, the interviewee in this example also mentioned the problem that suppliers need to adapt to the different requests. In addition, it can occur that the supplier's priorities and the personnel they provide changes as other, new/bigger clients place orders (interview E_Us 2018).
Required qualified personnel	**High (+)**	In the interviewee's experience, a general problem arises when suppliers offer a very good product, but the user is not able to properly apply the product,

		because the appropriate knowledge is missing. Thus, bringing user and supplier together is often a big challenge. This is why in this process, the user made sure they fully understood the product, in order to be able to take care of it, to solve problems, and also to be able to develop it further. Employees of the user had the required technical background, which was very useful.
Time	Medium (+/-)	After starting the implementation process, it turned out to be impossible to implement everything that had been planned at once. The interviewee would have preferred several smaller packages of action, which was impossible, because this would have required another number of tendering procedures (see above, "tendering procedure"). There was also time pressure due to an upcoming election, i.e., the new operational control center was planned to open before the election. This was fulfilled, i.e., the operational control system *(Einsatzleitsystem)* and a communication system *(Vermittlungssystem)* were implemented in time, however, several features including the disaster management system were only implemented afterwards. The system is continuously updated, sometimes in smaller, and sometimes in bigger steps. One of the bigger steps included the introduction of a mobile application for the system. Updates are usually based on upcoming IT developments, or the many suggestions from the users of the system (interview E_Us 2018).
Cooperation user – supplier	**High (+)**	As explained above, it can be challenging to match the product properly with the user's ability to effectively implement the solution in the organization, and make it usable in the best possible way. For this reason, it was very useful in this case that employees at the warning center possessed the required technical background, and participated fully in the implementation process. It was therefore possible to avoid a strong dependency on the supplier in case any issues with the system should arise (interview E_Us 2018).
Network	Low (+)	A network of relevant organizations was supportive and has even been seen to be improvable for future innovations. This relates to the intense cooperation required of the user and supplier as explained above, but also between different users, i.e., in this case different federal states. A stronger network and

		exchange could avoid work being carried out on similar issues in parallel, without them knowing about each other (interview E_Us 2018).

*Influence of an aspect considered low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

The results of the expert interview regarding innovation (E) "Compatible disaster management IT" system as presented in the three tables of this subchapter feed into chapter 6, in which the results of the expert interviews concerning all innovation examples are compared and evaluated.

5.8 Innovation F: Drone

5.8.1 Description of the innovation example

The use of drones at the fire brigade in Germany considered here is a result of research projects. This was especially possible through the fire brigades' own research institute. In 2008, when drones in general were still in the development phase, a project started to test and further develop drones for firefighting. For this project, two drones were acquired. The first one did not have a camera on board, in order to meet political concerns that society would have a critical attitude towards drones with cameras (spying etc.). It only had a sensor for measuring chemicals and sending the information to the ground. By the end of the project in 2011, both drone technology and political and societal attitudes had developed, and a second drone was bought, this time with a video camera. However, the camera's quality was too low for adequate use in real fire brigade operations. Thus, both drones were not yet convincing. Another, follow on project was a big success, and it was possible to implement all the fire brigade's targets. This project provided a new drone model with a high-resolution camera already on board. However, the real advantages were seen when the capacities of the drone were enhanced by adding a thermal imaging camera. The thermal imaging camera, which can provide huge benefits in operations, led to important changes in mindsets at management level. There was strong support for making the drone usable, and an operational concept was developed (interview F_Us 2018).

Following a period of training, the fire brigade's research institute handed over the drone to the regular fire brigade services. Since 2016, the drone has been a regular operating resource for the fire brigade. It is also included in the mission control computer, so it can be put on alert for operations. Another drone (the same model) was purchased, in case the first drone breaks and needs to be replaced. Apart from that, there is another, completely different drone, the result of a different research project: A drone comprising a sensor to measure radioactivity. Currently, work is in progress to make this drone deployable, to add a camera, and to attach a rechargeable battery system.

The drone with the video camera and thermal imaging camera has already been used in several operations, including operations in other cities or counties, which requested support from the drone. In these operations, it was clear how helpful the use of the drone is. The

supporting results include detecting blazes, and – theoretically – also persons (interview F_Us 2018).

5.8.2 Supporting and hindering determinants

The most relevant determinants as identified through an interview with a representative of the above-mentioned fire brigade, i.e. a user (operational level), who has also been involved in the drones' development, are described below.

Table 22 presents the determinants in the field of laws and policies that have been identified through the literature-based analysis (subchapter 4.3.1), and how – based on the expert interviews – these determinants were relevant for the implementation of innovation (F) "Drone".

Table 22: Determinants innovation (F) – laws and policies

Determinant	Influence*	Description
Information sharing		
Privacy and data protection regulations	Medium-High (-)	When the first drone project started in 2008, drones were not as popular and well-known as today, and the technology was not yet mature. In addition, there were political concerns about attaching a video camera to a drone, fearing the general public would not accept this. The first drone only had sensors for measuring chemicals in the air, so it was of limited use. By the end of this first drone project in 2011, there were fewer concerns in this regard. It was recognized that a drone needs a video camera to be useful. Thus, the second drone was developed with a video camera. However, the camera's quality was not very good, and the drone was never used in real missions. In 2016, the drone regulations were amended, which much enhanced the rights for fire brigades wanting to use drones. For example, it allowed drones to fly over crowds of people (previously, this had required special permits). Data encryption is necessary in order to secure the data collected in this way. Digital transmission technology is expected to make encryption easier. Since real time transmission is crucial, encryption should not lead to delays (Interview F_Us 2018).
Regulation on security of operational data	n/a	n/a
Freedom of information legislation	n/a	n/a

Cooperation & knowledge sharing		
Regulation on protection of intellectual property rights	n/a	n/a
Existence and use of standards	Medium (-)	Standardization has been an issue in the implementation process. Regarding the required training, a respective standard on federal state level is currently being developed (at the time of the interview in December 2018). The fire brigade so far uses its own regulation, which includes specific requirements for using a drone on a mission. This is different to the general drone license, which is not tailored to the needs of a fire brigade. Regarding technical aspects, what is still missing is – for example – a standard fixture to attach sensors to a drone, independent of the brand and model of the drone. Another possible standardization issue concerns data formats. It would be useful if (software) products from different suppliers were compatible. Standardization could become especially relevant in the context of drone swarms, which would require collaboration with other fire brigades nearby (Interview F_Us 2018).
Protection of employees & of the organization		
Employment protection legislation	n/a	n/a
Liability regulation	Low (-)	There are no clear regulations on liability in the context of drones. There are attempts to make sure that the drone is of high quality, and to assure that the pilot is adequately trained (and to be able to prove this). The interviewee expects that regulations will be developed as soon as something happens that will raise liability questions (Interview F_Us 2018).
External incentives		
Available financial resources	Medium (+)	Financing was not an issue, since the drones were financed through research projects funded by the German federal government. Without funding, the fire brigade is not able to conduct research. As soon as a drone becomes an official means of operation, financing will be covered by the fire brigade's budget (Interview F_Us 2018).
General political interest	Low (+)	The research projects funded by the federal government are aimed at the development of

		technologies that enable agencies and organizations with security tasks to be more effective (Interview F_Us 2018), which reflects political interest.
Legislation requesting assessments of/measures to increase resilience	n/a	n/a

*Influence of a determinant considered none/not identified (n/a), low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

Table 23 presents the organizational determinants that have been identified through the literature-based analysis (subchapter 4.3.2), and how – based on the expert interviews – these determinants were relevant for the implementation of innovation (F) "Drone".

Table 23: Determinants innovation (F) – organizational factors

Determinant	Influence*	Description
Staff and work process		
Commitment of individuals	**High (+)**	The commitment of individuals is always required, according to the interviewee, and this was also the case in the example of the drone. In the beginning of the process, it was not possible to demonstrate the actual benefits sufficiently. At a later stage, even the management level advocated the drone. However, it is also essential for employees on lower levels to be interested in the use of drones if drones are to be integrated in regular work (Interview F_Us 2018).
Dedicated unit in the organization	Medium (+)	Even though this was not addressed specifically in the interview, it can be assumed that without the existence of a dedicated research unit at the fire brigade, it would have hardly been possible to develop, test, and implement the drones, as was the case here.
Bureaucracy	n/a	The interviewee did not see any bureaucratic hurdles (Interview F_Us 2018).
Intra- and interorganizational cooperation and communication		
Internal communication	n/a	n/a
Consideration of employees' wishes and concerns	n/a	n/a
Interorganizational cooperation	n/a	See "Additional determinants/aspects": "Cooperation user – supplier".

Exchanging experiences with similar actors	Low (-)	There have been attempts to get into contact with other fire brigades working on the use of drones. But information is lacking on who is actually using drones/working on using drones. The interviewee tried to receive this information from a drone supplier, but for data protection reasons, the supplier did not reveal this information. A possible source would be if something is written in literature or media. However, a network of fire brigades for such an exchange would be desirable, but is missing so far. The interviewee sees difficulties in establishing such a network, since a Wiki for instance would require time and resources for development and maintenance (Interview F_Us 2018).
Trust	n/a	n/a
Innovation culture		
Openness towards innovations and change	n/a	n/a
Incentives for staff; possibility for experimentation	n/a	n/a
Compatibility of innovation-specific characteristics		
Visibility of the innovation's benefits	**High (+)**	It was important to convince the management level. For the first drone version, it was not possible to show the benefits convincingly, since it was not equipped with a camera. The next version however, equipped with a thermal imaging camera, was able to convince them. It was possible to demonstrate its benefits, especially through missions, leading to a change of mind regarding the use of drones. In addition, the general "hype" around drones supported this change of mind (Interview F_Us 2018).
Integration in daily work	n/a	See below under *Required knowledge and training*.
Easy to use	n/a	The drone is supposed to be used by staff who have a license. Thus, it is not possible or intended to be easily usable by everybody.
Costs	Low (+)	The main costs of adapting and developing the drones have been covered by research projects funded by the German federal government. See also *Available financial resources*.
Required knowledge and training	Low (+)	In addition to the training needed to gain a license, additional training courses are planned, since

		actual missions do not occur frequently (Interview F_Us 2018).
Required complementary technology/solutions	n/a	n/a

*Influence of a determinant considered none/not identified (n/a), low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

In addition to the predefined determinants, further aspects (possible new determinants) have been identified that were relevant for the implementation of innovation F "Drone", which are presented in Table 24.

Table 24: Additional aspects relevant for the implementation of innovation (F)

Aspect/Possible new determinant	Influence*	Description
Laws, policies		
(None)		
Organizational factors		
Cooperation user – supplier	Medium (+)	In this example, the user essentially participated in the development of the innovation, by collaborating with a supplier of drones. For example, the user saw the need to include propeller protectors. The supplier rejected the idea of adding a mechanical protection system. Together, a solution with a sensor-supported collision prevention system was found (Interview F_Us 2018).
Network	Medium (-)	As mentioned under *Exchanging experiences with similar actors*, a network of fire brigades using drones is missing, which could support collaboration, and the exchange of experiences. A strong network could also help in transferring the results of research projects into products (Interview F_Us 2018).

*Influence of an aspect considered low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

The results of the expert interview regarding innovation (F) "Drone" as presented in the three tables of this subchapter feed into chapter 6, in which the results of the expert interviews concerning all innovation examples are compared and evaluated.

5.9 Innovation G: Warning system

5.9.1 Description of the innovation example

The warning system enables government agencies and safety and security organizations that operate the system to send public warnings and behavioral advice to citizens via digital information channels, especially via smartphone apps. The system was developed by a Fraunhofer Institute in Germany, contracted by the German public insurance companies. It

has been in operation in Germany since 2011. The warnings are provided according to location, i.e., the warnings are sent to the people in the affected area, and those who selected the affected area as an area of interest in the mobile app installed on their device. The warning system is a technical distribution system, and therefore not restricted to any specific types of hazards. It is the decision of the responsible authority or organization to send a warning or not. In Germany, participating organizations include a number of local districts and independent municipalities; five federal states/city states; and, on a federal level, the German Meteorological Office *(Deutscher Wetterdienst)* when there is severe weather.[16]

After the warning system had been active for several years in Germany, it was also implemented in Austria in 2017. The process originated in a project on public alert systems in Austria. In this project, existing technology on alert systems was screened, and the German warning technology mentioned above was identified as most suitable for Austrian purposes (interview G_Us 2019). Austria now uses the technology, and is involved in its further development. It is available all over the country. In each event, the responsible organization (e.g. the warning center of the federal state affected) decides if a warning is sent to the population or not (interview G_Us 2019).

5.9.2 Supporting and hindering determinants

The most relevant determinants for the implementation process as identified through two interviews are described below. One interview was conducted with a representative of the responsible ministry in Austria, i.e., a user of the warning system (both at management and operational level), and one with a representative of a company that supports the implementation and operation of the system, i.e., a supplier (but also user) of the warning system.

Table 25 presents the determinants in the field of laws and policies that have been identified through the literature-based analysis (subchapter 4.3.1), and how – based on the expert interviews – these determinants were relevant for the implementation of innovation (G) "Warning system".

Table 25: Determinants innovation (G) – laws and policies

Determinant	Influence*	Description
Information sharing		
Privacy and data protection regulations	Low (-)	Data protection was an issue, since a mobile app constitutes a crucial element of the warning system. The new GDPR (see subchapter 4.3.1) came into force during the implementation process, with the effect that compliance had to be rechecked. One advantage in terms of data protection is that the mobile app is completely anonymous, i.e., it is not visible who is using the

[16] Website of the warning system (checked on 02/29/2020)

		app, and there is also no tracking. Finally, the new GDPR did not hinder the process, but it did cause additional workload (interview G_Us 2019).
Regulation on security of operational data	Low (-)	According to the supplier, the warning system is a highly secure system, which means that through encryption and secured lines, abuse is prevented. In addition, TAN numbers are requested for each release of a warning (interview G_Su 2019). Thus, while the security of operational data does not seem predominantly relevant in this example, it had to be ensured that the system is not abused.
Freedom of information legislation	n/a	n/a
Cooperation & knowledge sharing		
Regulation on protection of intellectual property rights	n/a	The use of the warning system is based on a license agreement (interview G_Us 2019; interview G_Su 2019). Public institutions provide the information on possible threats. This information is not related to any costs (interview G_Us 2019).
Existence and use of standards	n/a	n/a
Protection of employees & of the organization		
Employment protection legislation	n/a	n/a
Liability regulation	Low (-)	Questions of liability pose a general challenge in public warning systems. For example, if an event has been cancelled due to storm warnings, but in the end there is no storm, there might be financial losses. Or, if something untoward happens during the evacuation of people because of a warning (interview G_Us 2019). While no legal statement could be made in the interviews, it became clear that the responsibility and obligation of the state to deliver a warning are considered more important than the risks related to measures taken due to a warning (interview G_Us 2019; interview G_Su 2019).
External incentives		
Available financial resources	Low (+)	A low level of available financial resources contributed to the decision in favor of this specific warning system, due to its low costs

		(interview G_Us 2019). (See also below under *Costs*.)
General political interest	**High (+)**	There was awareness also on a political level (including the Austrian Minister of the Interior) regarding new technical possibilities as well as a changed security situation in Europe (e.g. due to terror attacks). Thus, an assessment of new warning systems had been mandated. The decision on a political level to finally purchase the warning system took some time but was most relevant (interview G_Us 2019; interview G_Su 2019).
Legislation requesting assessments of/measures to increase resilience	n/a	An EU Directive, the European Electronic Communications Code, amongst others, requests a warning system. However, the Directive was implemented just recently, and thus did not influence the implementation of this warning system (interview G_Us 2019).

*Influence of a determinant considered none/not identified (n/a), low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

Table 26 presents the organizational determinants that have been identified through the literature-based analysis (subchapter 4.3.2), and how – based on the expert interviews – these determinants were relevant for the implementation of innovation (G) "Warning system".

Table 26: Determinants innovation (G) – organizational factors

Determinant	Influence*	Description
Staff and work process		
Commitment of individuals	**High (+)**	Both interviewees see a decisive role in proper commitment, which did exist among individuals who pushed strongly for the overall introduction of the warning system in Austria. But the relevance also becomes clear when looking at the different regions, where differences in the intensity of using the warning system can be observed: While it is possible to use it only for disaster warnings, it can also be used for other warnings, e.g., tricksters' activities, or if a cablecar is out of service in a winter sports region. These options are used in different ways (interview G_Us 2019; interview G_Su 2019).
Dedicated unit in the organization	n/a	n/a
Bureaucracy	**Medium-High (-)**	Bureaucracy was an issue because implementation required a lot of time and effort. Anything that the federal government does has to be properly

		documented; requirements of procurement directives have to be met; and the GDPR (see above) required additional efforts. These issues were all clarified, but took more time and effort (interview G_Us 2019). In addition, agreements had to be developed with the federal states and communities. For example, it was necessary to ensure that the system is only used for security relevant information (interview G_Su 2019).
Intra- and interorganizational cooperation and communication		
Internal communication	**High (-)**	Communication processes between organizations or internal departments have influenced the implementation process significantly (interview G_Us 2019).[17]
Consideration of employees' wishes and concerns	Medium (+)	As explained for the determinant *Visibility of the innovation's benefits* below, the need to consider the location-specific requirements had been acknowledged and addressed, also taking care that nobody feels they are pushed into something, which was crucial for implementation (interview G_Us 2019).
Interorganizational cooperation	n/a	n/a. See *Cooperation user – supplier* in Table 27.
Exchanging experiences with similar actors	**High (+)**	It was considered very useful that in Austria the expertise and experience collected during the several years of the warning system's application in Germany could be used (interview G_Us 2019; interview G_Su 2019).
Trust	n/a	n/a
Innovation culture		
Openness towards innovations and change	Medium (+/-)	There seem to be differences in their openness towards innovations among the organizations that send out warnings. They have different levels of technical affinity, and different views on the previously existing system (sirens, loudspeakers). The reactions differed accordingly (interview G_Su 2019).
Incentives for staff; possibility for experimentation	n/a	n/a
Compatibility of innovation-specific characteristics		
Visibility of the innovation's benefits	Medium (+)	It was communicated that there are no monetary interests, that the system is useful, and that the different needs of the users are considered. This

[17] Details on this statement have not been provided.

		was important for the implementation process (interview G_Us 2019). This also meant that location-specific approaches were sometimes required, since different regions can have different needs (interview G_Su 2019).
Integration in daily work	Low (+)	It seems that integrating it in daily work was easy, because the general process of sending out warnings was not changed – just the means of warning (interview G_Su 2019).
Easy to use	n/a	n/a
Costs	**High (+)**	A crucial factor for the decision to implement this specific warning system was its low costs. Moreover, it was developed by a Fraunhofer institute, i.e. a non-profit organization. This enabled a collaborative cooperation, instead of e.g. being forced to pay extra costs for each adaptation that was required (interview G_Us 2019).
Required knowledge and training	Low (+)	Training courses were conducted with the warning centers to explain the functions of the warning system. However, using the warning system is simple. It also includes a test environment, in which warnings are only sent to their own apps. In addition, each year there is a test alarm for the sirens, which is now (since two years ago) complemented by warnings from this warning system (interview G_Us 2019).
Required complementary technology/solutions	Low (+)	The technical implementation is relatively easy, and no complementary technology is required (interview G_Us 2019; interview G_Su 2019).

*Influence of a determinant considered none/not identified (n/a), low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

In addition to the predefined determinants, further aspects (possible new determinants) have been identified that were relevant for the implementation of innovation (G) "Warning system", which are presented in Table 27.

Table 27: Additional aspects relevant for the implementation of innovation (G)

Aspect/Possible new determinant	Influence*	Description
Laws, policies		
Administrative burden due to federal structure	**High (-)**	In policing, for example, the federal level can take decisions that are binding for all federal states. However, in the field of disaster management the federal level only has a coordinating role. This means that the decision to issue warnings using the system lies with the competent authority that is legally

		responsible for dealing with a certain event. This can be the federal provinces, for example, in the course of weather events such as flooding or heavy snowfalls, or also certain ministries when it comes to health or radiation issues. Thus, several meetings and discussions were required, and it was necessary to communicate the advantages of the system well (see determinants *Visibility of the innovation's benefits* and *Consideration of employees' wishes and concerns*). Creating consensus was not simply a matter of course, also due to regional differences: For example, it would be desirable to have common criteria for sending out a warning, e.g., as soon as 10 cm of snow is reached. However, 10 cm of snow has different consequences depending on if it affects a big city like Vienna, or an area used to snow such as Tirol (interview G_Us 2019). The administrative burden caused by the federal structure of Austria has been confirmed by the interviewed supplier's representative, who sees strong differences to other clients from centralist states. While explicitly not criticizing federalist structures, the interviewee observed administrative issues strongly thwarting or prolonging an implementation process (interview G_Su 2019).
Tendering procedure	Low-Medium (-)	Meeting the requests in procurement directives has prolonged the overall process (interview G_Us 2019).
Organizational factors		
Cooperation user – supplier	**High (+)**	The strong collaboration between the German supplier and the Austrian user is considered as very useful. Support in technical terms, or related to, e.g., documents for public relations work and other exchange of experience was possible due to the long-term experience in Germany (interview G_Us 2019). The users' needs are integrated in further development processes, for example, based on a yearly conference where the suppliers present their new ideas, and the users (German as well as Austrian users) present what they like and what they miss in the current system. This information exchange strongly influences the further development of the system (interview G_Su 2019).
Ongoing further development of the solution	Low (+)	The warning system is a system that undergoes continuous further development, in line with other technological developments. When it originally started in Germany, it was an SMS-based system. With the development of mobile apps, these were also incorporated in the system. Similarly, it is currently

		being investigated as to how far 5G solutions can be integrated. The users are involved in the update processes, and all users receive the updated versions (interview G_Su 2019).

*Influence of an aspect considered low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

The results of the expert interviews regarding innovation (G) "Warning system" as presented in the three tables of this subchapter feed into chapter 6, in which the results of the expert interviews concerning all innovation examples are compared and evaluated.

6 Consolidation of results

Following the results of the literature-based analysis and the expert interviews, the results have now been merged and further evaluated. In subchapter 6.1, the relevance of predefined determinants (as derived from the literature-based analysis) for the example innovations that were recently implemented in disaster management to increase resilience (based on the expert interviews) is summarized and evaluated with regards to different types of innovation. In subchapter 6.2, additional and adapted determinants are derived based on the additional aspects identified in subchapters 5.3 – 5.9. Finally, subchapter 6.3 further evaluates the results and derives the new set of innovation determinants in disaster management to increase resilience, bringing together the findings from the literature-based analysis and the expert interviews.

6.1 Evaluation of the first set of determinants

In this subchapter, the influence of the determinants, which were predefined based on the literature analysis in subchapter 4.3, on the implementation processes of the example innovations (A-G) is summarized and evaluated. Table 28 and Table 29 present the level of influence of each predefined determinant per example innovation. (Table 30 in the following subchapter 6.2 presents the level of influence of additionally identified determinants (from the expert interviews) per example innovation.) The different types of innovation (see subchapters 1.4 and 5.1.2) are indicated in the tables as well.

As indicated in Table 28, *Privacy and data protection regulations* had a negative influence in four cases, while in the case of (F) "Drone" the influence was "high". The reason for this is that attaching a camera was decisive for the drone to become a really efficient tool for supporting firefighting. Regarding different types of innovation, the following can be noted: The determinant did not have any influence on the implementation processes of organizational innovations – except for the case of innovation (D) "Cooperative control center". However, the influence here refers to the new command system, which is part of the overall (organizational) innovation, but in itself would fall into the category of product innovations. The determinant did not have any influence on those innovations that improve an existing product or process. A possible explanation is that for this type of innovation, general issues such as data protection

requirements have already been clarified in advance and are less likely to come up when only improving existing solutions. Similarly, this could also be true for innovations imitating existing products. In this category, the determinant shows an influence on innovation (F) "Drone". However, the question of attaching a camera to a drone was a general issue, i.e., also affecting other drones, which a drone for firefighting "imitates".

The *Regulation on security of operational data* was relevant in three cases (negatively, i.e., complicating the implementation). The strongest influence was identified for example (D) "Cooperative control center". Here, it was an important requirement for the interface of the two IT systems to be configured to ensure secure data transfer and that information is not released. This has been especially relevant due to the involvement of the police and its specific requirements. Also in the case of (A) "National crisis management system", for which the influence of this determinant is assessed as "medium", dealing with security of operational data was relevant regarding the involvement of organizations that deal with security sensitive data, such as the police or the intelligence agency. Looking at the differences among innovation types, a similar pattern to that for *Privacy and data protection regulations* can be noted: The determinant is relevant for some product innovations, but not for organizational innovations, except for innovation (D) "Cooperative control center". However, here too the influence refers to the new command system. The determinant has an influence on the implementation of fundamentally new innovations, but none on those of innovations improving a product/process, or imitating existing products.

A negative influence of *Freedom of information legislation* is identified for the example (A) "National crisis management system". This is because the respective law allows the data stored in the crisis management system to be inspected, and decisionmakers might be afraid that this could be used in a wrong way, i.e., to blame them for something that goes wrong during a disaster. Since an influence of the determinants could be noted in one case only, it is not possible to draw any conclusions regarding different types of innovation.

The *Regulation on protection of intellectual property rights,* according to the expert interviews, did not have an influence on any of the example innovation implementations.

The *Existence and use of standards* was relevant in three examples. While the literature indicates both positive and negative influences of standards on innovation, the expert interviews can only confirm the positive version, i.e., the existence of standards supports innovation implementations/a lack of standards complicates innovation implementations. The influence of the determinant is assessed as "high" for the innovation example (D) "Cooperative control center". This is related to the heterogeneous system of control centers in Germany, and to the federal political structure. A lack of standards that has hampered the implementation process by absorbing extra effort and resources was mentioned with regard to control center specifications as well as procurement regulations. Also, the implementation processes for (A) "National crisis management system" and (F) "Drone" were negatively influenced by a lack of standards. This lack was related to data formats (A and F), and to technical specifications

(F). The determinant thus had a negative influence both on product innovations (A and F) and on organizational innovations (D). For the product innovations, the lack of standards is more technical (data formats, technical specifications), while in the case of organizational innovation, this lack has been associated with the federal political structure in Germany. Hence, while the literature tends to highlight the influence of technical standards, the expert interviews revealed both – the relevance of technical standards as well as nontechnical standards.

Employment protection legislation is not identified as having influenced any of the example innovations.

Influences by *Liability regulation* were identified in three cases, however "low-medium" was the highest level of assessment it achieved. The influence is always negative (while the literature indicates both positive and negative influences) and related to possible "mistakes" within an innovative solution or the behavior of decisionmakers/the users of the innovation, for which disaster management stakeholders could be blamed. All three cases pertain to product innovations – (A) "National crisis management system", (F) "Drone", and (G) "Warning system". This can be explained by the fact that "mistakes" within an organizational innovation might affect the organization itself more, and only indirectly affect the population in a less visible manner.

The determinant *Available financial resources* was relevant for all innovation examples. A lack of funding or budget hampered implementation, while circumstances where related costs were covered aided implementation. The reverse effect, i.e., increased motivation due to lack of resources, which was indicated in the literature, was not confirmed in any of the interviews. While an influence was identified in all cases and all innovation types, it seems that it was slightly higher for product innovations, and for fundamentally new innovations. This seems reasonable, due to the higher costs expected for these types of innovation.

General political interest was relevant in four cases, with positive correlation in each case, i.e., a supporting influence could be identified if there was appropriate interest on a political level. The two cases ranked "high" pertain to (A) "National crisis management system" and (G) "Warning system", which are both product innovations and fundamentally new innovations. Also here, the reason could be related to higher costs, potentially requiring stronger support for spending public money.

Legislation requesting assessments of/measures to increase resilience had a positive influence in one case only, but here it was classified as "high". The introduction of (A) "National crisis management system" was, amongst other things, based on the goal of enhancing information management as requested by the Dutch Safety Regions Act.

Table 28: Level of influence of laws and policies on the implementation of example innovations in disaster management to increase resilience

Determinant	A: National CM system (P; fund.)	B: Staff unit on R&I (O; impr.)	C: Innovation cluster (O; imit.)	D: Coop. control center (O; fund.)	E: Comp. DM IT system (P; impr.)	F: Drone (P; imit.)	G: Warning system (P; fund.)
Information sharing							
Privacy and data protection regulations	Low (-)	n/a	n/a	Low (-)	n/a	Medium-**High (-)**	Low (-)
Regulation on security of operational data	Medium (-)	n/a	n/a	**High (-)**	n/a	n/a	Low (-)
Freedom of information legislation	Low-medium (-)	n/a	n/a	n/a	n/a	n/a	n/a
Cooperation & knowledge sharing							
Regulation on protection of intellectual property rights	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Existence and use of standards	Medium (-)	n/a	n/a	**High (-)**	n/a	Medium (-)	n/a
Protection of employees & of the organization							
Employment protection legislation	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Liability regulation	Low-medium (-)	n/a	n/a	n/a	n/a	Low (-)	Low (-)
External incentives							
Available financial resources	**High (-)**	**High (-)**	Low (-)	Low (-)	Medium (+)	Medium (+)	Low (+)
General political interest	**High (+)**	Low (+)	n/a	n/a	n/a	Low (+)	**High (+)**
Legislation requesting assessments of/measures to increase resilience	**High (+)**	n/a	n/a	n/a	n/a	n/a	n/a

Innovation examples are product innovations (P) or organizational innovations (O); and fundamentally new (fund.), improving product/process (impr.), or imitating existing products (imit.).

Influence of a determinant considered none/not identified (n/a), low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

Table 29 summarizes the influence of organizational factors on the implementation processes of the example innovations.

By far the strongest influence of all determinants can be noted for *Commitment of individuals*, which is "high" for each innovation example. Thus, according to the expert interviews, personal commitment was decisive for successfully implementing each innovation. This includes the commitment of higher management (e.g., innovation (A) "National crisis management system", for giving priority and making financial resources available), but also of those people who actually work with an innovation (e.g., innovation (F) "Drone", to integrate the drone in their daily work), and of those leading the change process (e.g. innovation (D) "Cooperative control center", also transferring their passion to other people involved).

The existence of a *Dedicated unit in the organization* can be assumed to have been strongly supportive in the case of innovation (F) "Drone", since the drone was developed and tested in the fire brigade's own research unit. Also for innovation (C) "Innovation cluster", even though not explicitly mentioned, it was probably useful that R&I activities are concentrated in a dedicated unit at the organization that initiated the cluster. For the other innovation examples, an influence of this determinant cannot be identified. In several cases, such a unit does not exist, and the lack of such a unit is possibly not directly recognized, so it is not mentioned in the expert interviews. In the case of innovation (B) "Staff unit on R&I management", the innovation itself corresponds to this determinant. Thus, the relevance of a dedicated unit seems to be acknowledged to foster future innovations.

A negative influence of *Bureaucracy* has been identified in four cases. Especially for innovation (G) "Warning system", both interviewees found that bureaucracy has enormously complicated and prolonged the implementation process, e.g., due to documentation requirements, procurement regulations, GDPR requirements, and agreements required between federal states and communities. It seems that bureaucracy is hampering an implementation process of fundamentally new innovations more than it does for innovations improving a product/process or imitating an existing product. This might be caused by the (anticipated) greater change related to this type of innovation.

(A lack of) *Internal communication* hampered the implementation process in two cases, especially in the case of innovation (G) "Warning system". One could expect internal communication to play a more significant role than is reflected in these results. A possible explanation is that interviewees might have been reluctant to talk about such a sensitive internal issue.

The *Consideration of employees' wishes and concerns* was relevant in five cases. Where the consideration of employees' wishes and concerns is recognized to be adequately fulfilled, the influence is positive, i.e., supporting the implementation process. Where a lack of adequate consideration is noted, a negative influence, i.e., hampering the process, is noted. In the case

of innovation (D) "Cooperative control center", for which the influence is considered to be "high", employees co-designed the new working places, and for other aspects votes and interviews were conducted. This was seen as a crucial success factor. Significant deviations among the different types of innovation cannot be identified. However, it seems that for the implementation processes of fundamentally new innovations, considering employees' wishes and concerns was even more important than it was for innovations improving a product/process or imitating an existing product.

An influence of *Interorganizational cooperation* was identified in three cases. Here too, adequate cooperation leads to a positive influence and a lack of cooperation leads to a negative influence. Especially in the case of innovation (D) "Cooperative control center", the cooperation between the fire brigade, rescue services and others was seen to be strong and transparent, which is seen as a success factor.

The relevance of the determinant *Exchanging experiences with similar actors* is recognized in four of the examples. It is assessed as "high" for innovation (G) "Warning system". Here, the implementation process in Austria could benefit significantly from previous experience in Germany, where the system had been implemented for several years. In the other three examples the influence is considered to be "low".

The relevance of *Trust* is acknowledged in four cases. It is considered to have been decisive for the implementation processes of (B) "Staff unit on R&I management", and (C) "Innovation cluster". For the cluster, trust was a crucial element in bringing the different types of organizations together, as they do not usually collaborate in this way. Trust was very relevant for all examples of organizational innovation, but also for the product innovation (A) "National crisis management system". In this case it was, however, not related to the implementation of the actual IT system, but to the associated strengthening of cooperation between the organizations involved.

The general *Openness towards innovations and change* was an issue in five of the examples. In the case of innovation (B) "Staff unit on R&I management" ("high" influence), the interview partner sees a "natural hostility to innovation" within the organization, and finds that the fear of losing something was an important issue prolonging the implementation process. In contrast, in the case of innovation (D) "Cooperative control center", both interview partners consider the attitude towards innovation and change to be very open, which was very supportive for the implementation process. For innovation (G) "Public warnings", strong differences among user organizations were noted, resulting in different reactions towards the new system. The determinant seems to be relevant for all types of innovation – only for the innovations that imitate existing products ((C) and (F)) was no influence recognized.

A relevance of *Incentives for staff; possibility for experimentation* is identified in three cases. For innovation (D) "Cooperative control center" ("high" influence), the interviewed user sees a working atmosphere that allows e.g. communicating problems and mistakes to have been a

crucial success factor. Also here, no tendency among different types of innovation can be noted – except for the innovations that imitate existing products ((C) and (F)), for which no influence of the determinant was recognized.

An influence of the *Visibility of the innovation's benefits* on the implementation processes is noted in six cases. The influence is considered "high" for innovation (A) "National crisis management system", where negative examples of disaster responses with a lack of information sharing also highlighted the advantages of such a system. For (F) "Drone", the influence of the determinant is also considered "high", where it was possible to demonstrate the benefits of drones that are equipped with cameras. No significant deviation among different types of innovation can be recognized.

Integration in daily work was relevant for four innovation implementation processes. In the case of innovation (E) "Compatible disaster management IT system", emphasis was put on making the system usable and useful in non-crisis times as well, also by involving employees of the user organization in the implementation process. Here too, no significant deviations among different types of innovation are recognized.

The determinant *Easy to use* influenced the implementation process in three cases. This was an important issue especially for innovation (E) "Compatible disaster management IT system", and was specifically targeted in the development phase. The system is used by many people who do not work with it on a daily basis, including volunteers, so a system that is easily usable was required.

Costs were a factor in four cases. For the implementation of innovation (A) "National crisis management system", they had a "high" negative influence because it was not easy for the high costs to be covered by each of the organizations involved. For the implementation of (G) "Warning system", the influence was "high" and positive, because the low costs had strongly influenced the overall decision to implement the system. No influence was noted for the organizational innovations ((B), (C), and (D)). This seems reasonable, because it can be assumed that organizational changes are often only indirectly related to financial costs.

Required knowledge and training was considered relevant in four cases. For innovation (A) "National crisis management system", specific staff definitely needs appropriate knowledge and training. However, since this was addressed accordingly, the influence is considered to be positive. For this determinant too, no influence on organizational innovations could be noted. It seems understandable that knowledge/training is more likely to be required for new products than for organizational changes.

Required complementary technology/solutions was relevant in three cases. For innovation (A) "National crisis management system", a positive medium influence is noted because the technical implementation of the system is easy, not requiring any extra tools. Similarly, as for the previous determinants, an influence was noted for product innovations only, and none for

the organizational innovations. Also here, complementary technology/solutions are more likely to be necessary for new products than for organizational changes.

Following this evaluation of predefined determinants, additional new determinants derived from the expert interviews as well as adaptations to the predefined determinants will be presented in subchapter 6.2.

Table 29: Level of influence of organizational factors on the implementation of example innovations in disaster management to increase resilience

Determinant	A: National CM system (P; fund.)	B: Staff unit on R&I (O; impr.)	C: Innovation cluster (O; imit.)	D: Coop. control center (O; fund.)	E: Comp. DM IT system (P; impr.)	F: Drone (P; imit.)	G: Warning system (P; fund.)
Staff and work process							
Commitment of individuals	**High (+)**	**High (+)**	**High (+)**	**High (+)**	**High (+)**	**High (+)**	**High (+)**
Dedicated unit in the organization	n/a	n/a	Low (+)	n/a	n/a	Medium (+)	n/a
Bureaucracy	Low-Medium (-)	Low (-)	n/a	Low (-)	n/a	n/a	Medium-**High (-)**
Intra- and interorganizational cooperation and communication							
Internal communication	n/a	Low (-)	n/a	n/a	n/a	n/a	**High (-)**
Consideration of employees' wishes and concerns	Medium (+)	Medium (-)	n/a	**High (+)**	Low (+/-)	n/a	Medium (+)
Interorganizational cooperation	Medium (+)	n/a	Medium (-)	**High (+)**	n/a	n/a	n/a
Exchanging experiences with similar actors	n/a	Low (-)	n/a	Low (+)	n/a	Low (-)	**High (+)**
Trust	Medium (+)	**High (+)**	**High (+)**	Medium (+)	n/a	n/a	n/a
Innovation culture							
Openness towards innovations and change	Low (+)	**High (-)**	n/a	Medium (+)	Low (+)	n/a	Medium (+/-)
Incentives for staff; possibility for experimentation	Low (+)	Low-medium (-)	n/a	**High (+)**	n/a	n/a	n/a
Compatibility of innovation-specific characteristics							
Visibility of the innovation's benefits	**High (+)**	Medium (-)	Medium - High (+)	Low (+)	n/a	**High (+)**	Medium (+)
Integration in daily work	Low (+)	n/a	n/a	Medium (+)	Medium (+)	n/a	Low (+)

Easy to use	Low (+)	n/a	n/a	Low (+)	Medium (+)	n/a	n/a
Costs	**High (-)**	n/a	n/a	n/a	Medium (-)	Low (+)	**High (+)**
Required knowledge and training	Medium (+)	n/a	n/a	Low (+)	n/a	Low (+)	Low (+)
Required complementary technology/solutions	Medium (+)	n/a	n/a	n/a	Low (+)	n/a	Low (+)

Innovation examples are product innovations (P) or organizational innovations (O); and fundamentally new (fund.), improving product/process (impr.), or imitating existing products (imit.). Influence of a determinant considered none/not identified (n/a), low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

6.2 Evaluation of additional aspects identified in the expert interviews

In addition to the evaluation of predefined determinants in the context of the example innovations, additional determinants have been identified based on the expert interviews, as presented in Table 30. These additional determinants are derived from additional aspects that have been listed and described at the end of each sub subchapter 5.2-5.9. In addition to the new determinants, the additional aspects in some cases lead to adaptations to the existing, predefined determinants. In the following, the new determinants and the adapted predefined determinants are explained. Further, other additional aspects have been identified in the expert interviews that seem to be solution specific, i.e., they are barely transferable to other innovations. They did not result in new or adapted determinants but are described under "Case-specific additional aspects".

New determinants

In the context of innovation example (D) "Cooperative control center", the heterogeneous structure of local control centers has been mentioned as having an important influence on innovation activities. The heterogeneity can partly be explained by different geographical conditions, or different attitudes and commitments of relevant personnel (see determinant *Commitment of individuals*). However, due to the federal political structure in Germany, control center laws *(Leitstellengesetze)* differ among the German federal states, which is another reason for the different specifications for control centers. In addition, as in the case of innovation (D), it can be a requirement to bring together different levels of governance such as the communities, the counties, and at federal state level, which can be challenging. The latter has also caused an additional administrative burden in the context of innovation example (G) "Warning system": In general, the federal level only has a coordinating role in the field of disaster management. The responsible authority that decides to issue public warnings depends on the type of the event; it can be a federal state, but also a ministry at federal level. Thus, agreement among several organizations and levels of governance was required. These issues are summarized under a new determinant *Heterogeneous structure/administrative burden due to the federal political system,* which appears to have possible impact on any innovation implementation processes in federal countries.

Hurdles related to *Tendering regulations* have been identified for innovation (D) "Cooperative control center", (E) "Compatible disaster management IT system", and (G) "Warning system". Meeting the demands of tendering regulations can lead to enormous amounts of effort, and the absence of a standard for tendering platforms can cause additional difficulties for applicants. It can even occur that a tendering platform does not meet the security standards of a user organization. Plus, in the case of innovation (E), for example, the user tried to cover a long list of requests in one tender, in order to avoid several tendering procedures. This had an impact on the implementation process because it turned out to be challenging to implement all these issues at once. While *bureaucracy* relates to internal rules and procedures, *Tendering regulations* include externally defined requirements that an organization has to fulfill. Based on the literature analysis, the relevance of *Tendering regulations* on innovation implementations

in disaster management was considered to be not strong enough to be included in the first set of determinants. However, "tendering and contracting issues" were, for example, identified by Cinar et al. (2019) as constituting a barrier to public sector innovation. Since the expert interviews revealed significant influence, the determinant has now been added to the new set of determinants.

Further, the new determinant *Time* is added: For the innovation examples (A), (B), (D), (E), (F), and (G) it was observed that further development and/or implementation of the innovation over time was extremely relevant. The implementation of innovation (A) "National crisis management system", for instance, took many years. This allowed the high number of organizations involved and different governmental levels to be coordinated, and provided the opportunity to improve the system based on lessons learned. It was even called "one of the secrets" of the system's successful implementation. The effective work of the (B) "Staff unit on R&I management" did not start right away either, but required a learning process of about two years. For innovation (D) "Cooperative control center", some flexibility in deadlines was required. Both innovation (E) "Compatible disaster management IT system" and (G) "Warning system" demand continuous updates, including updates based on new IT developments. For innovation (F) "Drone", even though "time" was not explicitly mentioned in the interview, the description of the overall implementation process shows that several years were required, including the acquisition of several drones, and execution of several projects, until drones could finally be successfully deployed to support firefighting. Hence, an indispensable requirement for successfully implementing an innovation can be the provision of sufficient time, and possibly continuous adaptations (IT updates; "learning by doing"), or flexible deadlines.

The new determinant *Specific needs, impossible to be addressed by supplier* is mainly based on observations related to the implementation processes of the innovations (D) "Cooperative control center", and (E) "Compatible disaster management IT system". Difficulties for suppliers related to the generally small and specialized market of disaster management (as described in subchapter 2.2) were recognized in the context of innovation (D). The small market with differing needs can even lead companies to give priority to new or bigger clients at the expense of running projects. This was mentioned in the context of both innovations (D) and (E). The determinant can – but does not have to – be related to the determinant *Heterogeneous structure/administrative burden due to the federal political system*. In context of innovation (D) for example, it was mentioned that the heterogeneous structure with differing specifications of control centers lead to differing requests, which can add to the difficulties of companies to answer the requests of users. While not referring to the specific innovation example (F) "Drone", also the user interviewee of innovation (F) points to the general issue that in many cases, in the perception of suppliers, the market is too small for a positive "return on investment" (Interview F_Us 2018). The determinant is hence closely related to the general market conditions of disaster management, as explained in subchapter 2.2.

In addition, a new determinant *Cooperation user – supplier* complements the new set of determinants. Whereas the determinant *Interorganizational cooperation* addresses cooperation among user organizations, the cooperation between user and supplier can also be decisive in an implementation process. This has been identified for the implementation processes of the innovation examples (E), (F), and (G). In the case of innovation (E) "Compatible disaster management IT system", it was reported that some employees at the warning center were intensively involved in the implementation process, which was possible because they had the necessary technical background. This helped to adapt the innovation to the user's needs, and at the same time avoided a stronger dependency on the supplier in case of any technical issues. Innovation (F) "Drone" was developed in close cooperation between the user (fire brigade) and the supplier (producer of drones). This was an essential condition for developing a drone that could be used for firefighting. The close cooperation between the supplier and user of innovation (G) "Warning system" was very useful as well, e.g., in terms of technical support or the provision of documents by the supplier.

Table 30: Level of influence of additional aspects on the implementation of example innovations in disaster management to increase resilience

Identified additional aspects	A: National CM system (P; fund.)	B: Staff unit on R&I (O; impr.)	C: Innovation cluster (O; imit.)	D: Coop. control center (O; fund.)	E: Comp. DM IT system (P; impr.)	F: Drone (P; imit.)	G: Warning system (P; fund.)
Aspects leading to new determinants							
Heterogeneous structure/administrative burden due to the federal political system				**High (-)**			**High (-)**
Tendering regulations				Medium (-)	Medium (-)		Low-Medium(-)
Time	**High (+)**	**High (+)**		**High (+)**	Medium (+/-)	Medium (+)	Low (+)
Specific needs, impossible to be addressed by supplier				Medium-High (-)	Medium (-)		
Cooperation user – supplier					**High (+)**	Medium (+)	**High (+)**
Aspects leading to adaptations of predefined determinants							
Required qualified personnel	Medium (-)			Low (+)	**High (+)**		
Personal contacts		**High (+)**	**High (+)**				
Network				Medium (-)	Low (+)	Medium (-)	
Case-specific additional aspects							
Efficiency principle				Medium (-)			
Dependency on a company that is not in the market	Low (-)						
Need to give up own solutions; decreasing influence on lower level when using a joint solution	Medium (-)						

Innovation examples are product innovations (P) or organizational innovations (O); and fundamentally new (fund.), improving product/process (impr.), or imitating existing products (imit.).
Influence of an aspect considered none/not identified (n/a), low, medium, or high; predominantly supporting (+) or hindering (-) the implementation.

Adapted predefined determinants

For the innovations (A), (D), and (E), the availability of qualified personnel has been identified as having influenced the innovation processes. In case of innovation (A) "National crisis management system", it is the expertise of the "information managers" that is of utmost importance, since they decide about the information that is fed into the system. For innovation (D) "Cooperative control center" employees with adequate IT expertise were required, and also in the case of innovation (E) "Compatible disaster management IT system", employees of the user had technical knowledge that enabled a proper understanding of the innovation, including the ability to independently refine the system. In the private sector context, Thielmann et al. (2009), for example, had also identified a lack of qualified personnel to present an innovation barrier related to key technologies. Based on the overall literature analysis however, the significance for this study was considered not to be strong enough to include "qualified personnel" in the first set of determinants. But since the expert interviews revealed a significant influence, the issue is included in the new set of determinants. Due to its close relationship to required knowledge and training, the predefined determinant *Required knowledge and training* has been adapted to become *Required knowledge, training, and qualified personnel*.

Establishing and maintaining personal contacts to related organizations seems to be supportive in many cases. However, it was specifically observed in the implementation processes of innovations (B) "Staff unit on R&I management" and (C) "Innovation cluster". Initiating the innovation cluster for instance, where competing organizations are involved, required a respective level of trust, which, following the related expert interview, was only possible through the existing personal contacts. Hence, personal contacts are strongly interlinked with trust, and thus the predefined determinant *Trust* has been extended to become *Personal contacts & Trust*.

The predefined determinant *Interorganizational cooperation* addresses collaboration traditions among different user organizations. In addition, the analysis of innovations (D), (E), and (F) showed that the existence of an institutionalized network was supportive (such as an association of control centers for rescue services, innovation (D) "Cooperative control center") – or would have been useful (such as a network of fire brigades using drones, innovation (F) "Drone"), to foster the innovation implementation processes. Hence, the predefined determinant has been adapted to become *Interorganizational cooperation & networks.*

Case-specific additional aspects

It seems that the *Efficiency principle* (see explanation related to innovation (D) in subchapter 5.7.2) can be most relevant for envisaged innovations in control centers for rescue services. However, since this is not transferable to other organizations, it is not included in the new set of determinants

A *Dependency on a company that is not in the market*, which was identified for innovation (A) (see explanation in subchapter 5.3.2) could be relevant for other IT-related innovations, for which

the supplier organization does not compete with other suppliers of IT solutions. Since these are specific cases, the aspect is also considered to be "case specific".

Also related to innovation (A), a *Need to give up own solutions; decreasing influence on lower level when using a joint solution* was identified as having slightly hindered the process (see explanation in subchapter 5.3.2). This could be transferable to other innovations on a high level (e.g. national) that replace solutions on lower levels (e.g. regional). But these also seem to be specific cases, hence this determinant has not been added to the new determinants.

6.3 Summary and new set of determinants

Following the evaluation of expert interviews and comparisons to the results of the literature-based analysis, an adapted set of determinants has been defined, i.e., factors that influence the implementation of innovations in disaster management to increase resilience, see Figure 8 and Figure 9.

The new set includes five new determinants, as described in subchapter 6.2. Two of them address laws/policies, the other three represent additional organizational determinants. The first new determinant, *Heterogeneous structure/administrative burden due to the federal political system,* is assigned to the category "Cooperation & knowledge sharing", and the second one, *Tendering regulations,* is assigned to the category "External incentives". The new organizational determinant *Time* is added to the category "Innovation culture", *Cooperation user – supplier* now belongs to the category "Intra- and interorganizational cooperation and communication", and *Specific needs, impossible to be addressed by supplier* became part of "Compatibility of innovation-specific characteristics". The adaptations of predefined determinants affected only organizational determinants.

Comparing the relevance of determinants identified for the example innovation implementations, the following can be noted: Among the predefined determinants (see subchapter 6.1), the determinant *Commitment of individuals* stands out with "high" relevance for each example innovation implementation. The personal commitment can hence be seen to be decisive, be it the commitment of higher management level (e.g. for giving priority and making financial resources available), or those people who actually work with an innovation (e.g. to take care of proper integration into existing working procedures), or any other individuals leading the change process. It is further noteworthy that the determinant *Available financial resources* also had an influence on all example innovation implementations, although the level of influence ranges from "low" to "high". In addition, *Time* (a new determinant, see subchapter 6.2) can also be extremely important; its influence has been considered "high" for three of the examples. Hence, individuals committed to the innovation, available financial resources, and allowing continuous adaptations and learning processes over time present essential conditions for successfully implementing an innovation.

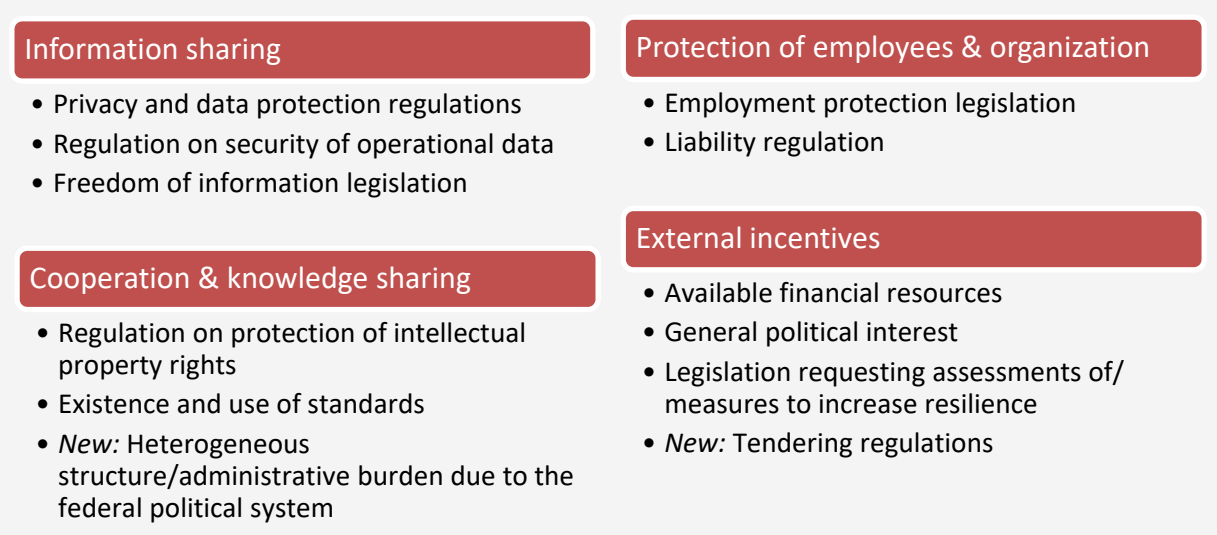

Figure 8: New set of innovation determinants in disaster management to increase resilience – laws, policies

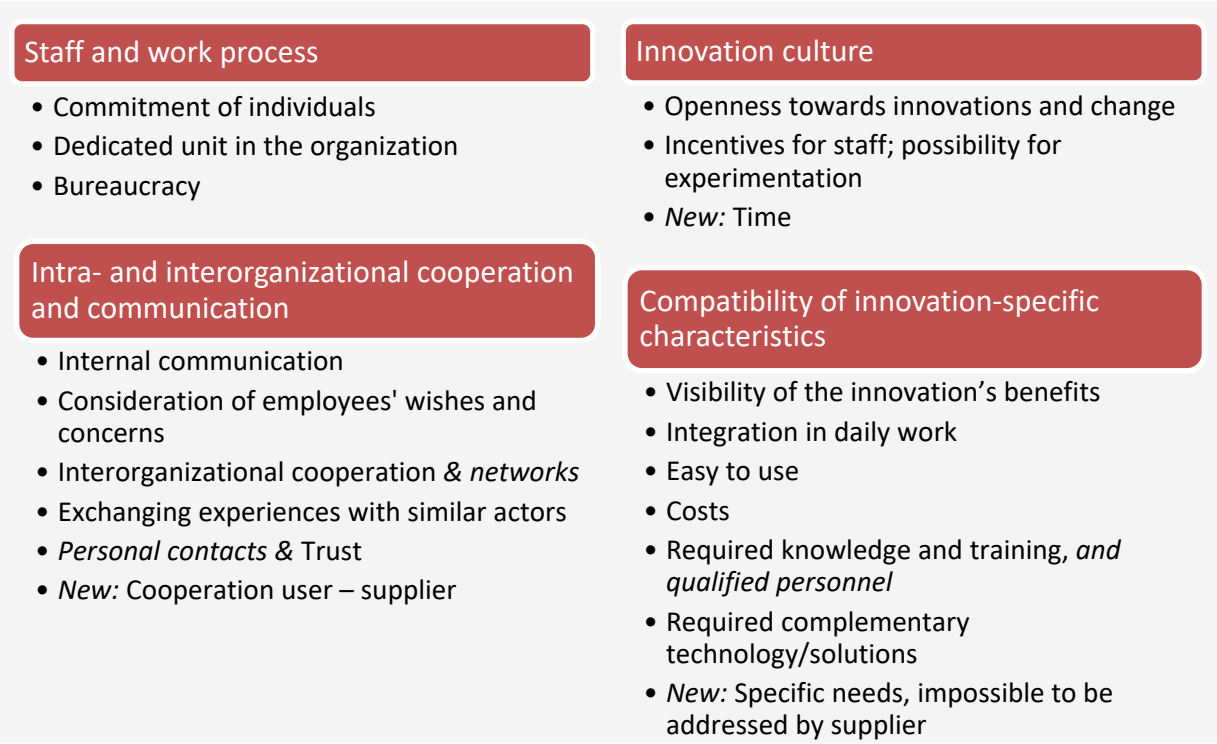

Figure 9: New set of innovation determinants in disaster management to increase resilience – organizational factors

Further, the influence of the following six determinants (predefined as well as new and adapted determinants) has been considered "high" for at least two examples: *General political interest, Heterogeneous structure/administrative burden due to the federal political system, Personal contacts & Trust, Visibility of the innovation's benefits, Costs, and Cooperation user – supplier.* In contrast, relevance of the determinants *Freedom of information legislation* and *Legislation requesting assessments of/measures to increase resilience* could only be identified in one case.

No influence could be confirmed for *Regulation on protection of intellectual property rights* and *Employment protection regulations*. Effects of employment protection regulations on innovation seem to be mainly based on unconscious behavior, therefore possibly not identifiable through interviews. In addition, the literature suggests different effects of employment protection (as well as of intellectual property rights), i.e., supporting vs. hindering innovation (see subchapter 4.3), which possibly further hampers the identification of an influence in practical examples. The fact that two determinants could not be confirmed through expert interviews does not necessarily confirm their irrelevance, so they have not been removed from the set of determinants.

For three other determinants the literature proposes an influence that can be both supportive and hindering (see subchapter 4.3), whereas the results of the expert interviews confirm only one direction: *Existence and use of standards* (only confirmed that a lack of standards possibly hinders innovation implementation), *Liability regulation* (only confirmed that liability regulation can cause reluctance to implement an innovation), and *Available financial resources* (only confirmed in the way that available resources support/a lack of resources hinders innovation implementations).

Observed differences in the effects of determinants on innovation implementations by different types of innovation (distinguishing between product and organizational innovations as well as between fundamentally new innovation, innovation improving existing product/process, and innovation imitating existing products) have been described in subchapter 6.1. In general, a tendency can be observed that innovation implementations tend to be more strongly influenced by determinants if the innovation is a product innovation, and if it is a fundamentally new innovation. Reasons for this could be the possible higher (direct) costs related to these types of innovation, which then requires more support from other factors. In addition, differences in the relevance of determinants for product innovations as compared to organizational innovations become apparent, i.e., there is a tendency that a determinant either strongly influences product innovations *or* organizational innovations. In contrast, differences regarding the degree of innovation are less clear, except for the observation that influences in general seem to be stronger on fundamentally new innovations. Additionally, a tendency can be noted that organizational innovations are less influenced by laws and policies, and are more influenced by organizational determinants.

Table 31 and Table 32 include the new set of determinants with short descriptions of each determinant. The relevance of a determinant for an innovation implementation can differ not only depending on the type of innovation as mentioned, but also depending on specific characteristics of the innovation, or context factors such as the political system. Respective recognitions are included in the tables by presenting information on innovation implementations that can be expected to be influenced by the determinants.

The new set of determinants addressing laws and policies is presented in Table 31.

Table 31: Overview new set of innovation determinants in disaster management to increase resilience – laws, policies

Determinant	Short description	Innovation implementations expected to be affected
Information sharing		
Privacy and data protection regulations	This determinant reflects the possible clash between personal information being required for effective disaster management, and data protection rights. A main part is manifested in the GDPR, which came into force in May 2016. In addition to the direct effects of privacy and data protection regulations, a lack of clarity or knowledge about the application of pertinent regulations can also hinder innovation implementations.	This determinant could be relevant for product innovations that collect or deal with personal data (e.g. disaster management IT system; social media tools). Fundamentally new innovations seem more likely to be affected, because for other types of innovation, data protection issues were possibly already clarified in earlier stages.
Regulation on security of operational data	In addition to personal data, the handling of sensitive operational data (e.g. classified data) also requires a proper balance between providing necessary information for adequate disaster management, and the risk of revealing sensitive information. Here too, not only is the direct effect of respective regulations relevant, but also possible uncertainties about restrictions.	The determinant could be relevant for product innovations that deal with information that includes or can include sensitive operational data. This is for example the case when organizations such as the police or an intelligence agency use a common IT system for sharing information with other organizations. Fundamentally new innovations seem more likely to be affected.
Freedom of information legislation	Freedom of information legislation ensures the right of individuals (including, e.g., journalists) to review documents and records of public organizations. This entails the possibility that an inspection of information collected and stored by a public	Especially IT solutions, i.e. product innovations which collect data about the activities of public disaster management organizations could be affected.

	disaster management organization is requested. The provision of such data can be difficult, or entail the concern that the data is used to blame the organization for potentially wrong decisions. This can deter organizations from implementing an innovation that collects such data.	
Cooperation & knowledge sharing		
Regulation on protection of intellectual property rights	Whereas the relevance of the determinant could not be confirmed in the expert interviews, evidence can be found in the literature in selected cases. IPR regulations can, for example, be hindering in the context of satellite technology for disaster management relief (Cabrera-Alvarado et al. 2013), or related to the use of social media (Crowe 2012). Similarly as for the two previous determinants, legal uncertainty related to IPR can also be hindering to innovation implementation.	Organizational innovations seem to be unlikely to be related to IPR issues. However, product innovations that rely on information or other goods that are protected by, e.g., copyrights, trademarks or patents could possibly be affected. The majority of information required for disaster management is free of charge and not subject to IPR. However, the examples of satellite imagery and social media show that IPR can possibly be relevant for innovation implementations in disaster management.
Existence and use of standards	Standards can influence innovation processes in a positive or negative way, while the expert interviews only confirmed the positive version, i.e., a lack of standards has complicated the innovation implementations.	Standards can be relevant for different kinds of innovation, including product as well as organizational innovations. While technical standards are more relevant for product innovations, nontechnical standards can also influence organizational innovations.
New: **Heterogeneous structure/administrative burden due to the federal political system**	A heterogeneous structure of organizations can lead to difficulties in joint procurement and/or innovation, as well as for suppliers to satisfy the different needs. Such a heterogeneous structure can	The determinant can influence an innovation that is implemented on a higher level, where different levels of governance are involved. Or, if a heterogeneous structure has caused limited

	develop (or be strengthened) if the political system is a federal system. A federal system can also hamper agreements or cause additional administrative efforts if several governmental levels and organizations are involved.	possibilities on the suppliers' side, it can affect any product innovation provided by this supplier.
Protection of employees & of the organization		
Employment protection legislation	Employment protection legislation can have a positive effect on innovation, if employees are motivated by the perspective of profiting from the innovation in the future. However, negative effects are also possible, if responsible staff becomes hesitant due to an increased risk of failure that comes with an increased motivation of employees to innovate. The determinant was not confirmed in the expert interviews, and is based on literature only.	The literature indicates that in the private sector, employment protection legislation can motivate innovation that improves an existing product or process but rather hinders fundamentally new innovations. This could also be true for the disaster management sector, however, evidence is missing.
Liability regulation	Liability regulations can also both support innovation (if the innovation helps to fulfill liability requirements) and hamper innovation (e.g., if the regulations lead to a hesitation to share data). The influence of liability regulations identified through expert interviews was only negative, i.e., innovation implementations were hampered. However, the influence was not high.	Product innovations are more likely to be affected than organizational innovations, especially if these innovations entail collecting or sharing data that the organization is responsible for.
External incentives		
Available financial resources	In the same way as for the previous two determinants, regarding budget constraints the literature also indicates both positive and negative effects. While a lack of resources can trigger innovative behavior, available budgets can also be an	The determinant is highly relevant, and can principally affect all types of innovation. However, innovations with higher costs, as often related to fundamentally new product innovations, can be

	indispensable requirement for innovation. The influence identified for the example innovations, however, only indicates the latter – available resources were required for implementing the innovations.	expected to be affected more strongly.
General political interest	The determinant relates to interests on a political level, e.g., triggered by societal developments, which essentially influence decisions on a political level to support an innovation or not.	The determinant is relevant for those innovations that require support on a political level. These are often innovations that are related to higher costs, which is more likely for product innovations and fundamentally new innovations.
Legislation requesting assessments of/measures to increase resilience	Legislation requesting an organization to act can push innovation activities, which can be any legislation established to increase the resilience of society by means of enhanced disaster management.	The determinant can be relevant for all innovations intending to enhance any task in the context of disaster management.
New: **Tendering regulations**	Tendering regulations can cause enormous administrative effort (on top of other bureaucratic issues), which can be multiplied by the diverging demands of different tendering platforms. This large amount of effort can even tempt users to include a long list of needs and requirements in one tender, trying to avoid the need for several tenders, which is then difficult to implement in practice.	The determinant can affect any innovation that is intended to be procured by a public disaster management organization. This is likely to be true for product innovations, however, it could also affect an organizational innovation that requires a procurement of services.

Following the overview of determinants addressing laws and policies, the new set of organizational determinants is presented in Table 32.

Table 32: Overview new set of innovation determinants in disaster management to increase resilience – organizational factors

Determinant	Short description	Innovation implementations expected to be affected
Staff and work process		
Commitment of individuals	The commitment of individuals is decisive, as confirmed by the literature, and especially by the expert interviews ("high" relevance in each innovation example). It includes commitment of management or other staff members ("innovation champions") as well as commitment of external individuals.	All types of innovation are expected to be affected.
Dedicated unit in the organization	A dedicated unit on research & development or innovation exists only in exceptional cases in public disaster management organizations. However, if such a unit exists, this can be a powerful advantage for implementing innovations.	This determinant is also expected to possibly affect all types of innovation.
Bureaucracy	Bureaucracy includes internal rules and procedures as well as the assumptions and behavior that these rules and procedures induce. It is a factor typically assigned to the public sector. It can prevent, complicate, or prolong innovation processes.	Whereas the determinant can principally affect all types of innovation, it seems that it is more likely to hamper implementation processes of fundamentally new innovations, because this type of innovation implicates (anticipated) bigger changes.
Intra- and interorganizational cooperation and communication		
Internal communication	Inadequate internal communication flows can constitute a major barrier to innovation implementation. Good communication is especially important for conveying the benefits of an innovation.	The determinant can principally affect all types of innovation. Organizational innovations in particular might cause fear or uncertainties among employees, which possibly makes this determinant especially relevant to this type of innovation. However, there is no evidence based on the expert interviews.

Consideration of employees' wishes and concerns	Related to internal communication, the consideration of employees' wishes and concerns can also influence an innovation implementation process. Employees are a crucial part of change processes, and their attitude towards these changes is vital.	This determinant can be relevant for all types of innovation. It can be assumed that the bigger the (anticipated) change for employees, the more important is the consideration of their wishes and concerns.
Interorganizational cooperation *& networks*	Cooperation of different disaster management organizations, manifested in collaboration traditions or institutionalized networks can be supportive for innovation implementations.	The determinant can be relevant for any innovation that involves several organizations, such as a joint disaster management IT system. It can also be relevant for other innovations, for which knowledge exchange and/or a joint innovation implementation could be useful (see determinant *Exchanging experiences with similar actors*).
Exchanging experiences with similar actors	Exchanging experiences and getting to know about possible requirements or barriers that similar actors have experienced can be supportive for an innovation implementation.	In principle, this determinant can be relevant for any type of innovation. Nevertheless, it is more likely that information can be gained about previous experiences for innovations imitating existing products, especially if it has already been implemented in the disaster management domain.
Personal contacts & **Trust**	A lack of trust among employees within an organization as well as between organizations can present a barrier to innovation. In this context, personal contacts can play an essential role. This seems to be especially true for the disaster management domain, where different organizations need to collaborate, while this collaboration is often not formalized.	Whereas personal contacts and trust are also relevant within an organization, it seems to be especially important for cross-organizational innovations.
New: **Cooperation user – supplier**	Whereas the determinant *Interorganizational cooperation*	Relevance of the determinant has been especially identified

	addresses cooperation among user organizations, the cooperation between user and supplier can also be crucial in an implementation process. Close cooperation allows the innovation to be implemented in a way that it is most useful for the user, by adapting it to the user's specific needs.	for technical (e.g. IT) product innovations.
Innovation culture		
Openness towards innovations and change	Whether an organization is open towards innovation depends on individual attitudes and characteristics as well as organizational structures and the general organizational climate.	This determinant can be relevant for all types of innovation.
Incentives for staff; possibility for experimentation	Related to the previous determinant, working conditions that encourage staff to innovate (e.g. through financial rewards or other types of recognition), and/or provide possibilities for experimentation (allow mistakes) can be supportive for innovation.	This determinant can be relevant for all types of innovation.
New: **Time**	Instead of quick and abrupt implementation processes, for innovations to be successful, implementation can take some time. This allows learning processes and continuous adaptations to be included, in order to make the innovation more useful and usable for the organization.	This determinant can be relevant for all types of innovation. For IT solutions, continuous updates seem to be a general requirement.
Compatibility of innovation-specific characteristics		
Visibility of the innovation's benefits	The perceived benefits of an innovation are important to encourage employees and other relevant actors to support the implementation process. Thus, the benefits should be visible.	This determinant can be relevant for all types of innovation.
Integration in daily work	If a disaster management solution is supposed to work in times of disaster, people working with the solution should be familiar with it, and the usability	This determinant can be relevant for all types of innovation. Familiarity seems especially relevant for

	should be proven prior to an event. These conditions can be accomplished by integrating the solution in the daily work of a disaster management organization.	technical innovations, such as complex IT solutions.
Easy to use	In general, the complexity of (e.g. IT) solutions presents a barrier to successful innovation implementation. Especially in disaster management, ease of use can be essential, since they have to work in non-daily situations, and when the users are under stress.	Especially for product innovations in terms of IT solutions, it can be challenging to enable vital functions while keeping the software easily usable at the same time.
Costs	In addition to the general availability of resources, the success of a specific innovation implementation can also depend on its individual costs.	For product innovations, related financial costs are usually more obvious than for organizational innovations. In addition, if costs are higher, of course the hurdles they create can be bigger as well.
Required knowledge, training, ***and qualified personnel***	The introduction of a new tool or way of working may require appropriate knowledge and/or adequate training for those who will apply the innovation. In specific cases, specific knowledge may even be required, and thus appropriately qualified personnel.	Knowledge, training, and appropriately qualified personnel are more likely to be relevant for product innovations than for organizational innovations.
Required complementary technology/solutions	An innovation in an organization potentially only works if it is compatible with existing technology or other procedures.	Complementary technology or solutions are more likely to be necessary for product innovations than for organizational innovations.
New: **Specific needs, impossible to be addressed by supplier**	This new determinant is related to the small market of disaster management, which is sometimes challenging to address for suppliers. Only a few clients in total, which can also have differing needs and demands, can cause a barrier to successful innovation implementation.	Since in many cases organizational innovations do not require "suppliers", product innovations are more likely to be affected.

The new set of determinants as presented in this subchapter provides an answer to the main research question: *"Which LPO determinants hinder or support a successful implementation of innovations in disaster management to increase resilience in the EU, and how?"* The results will be discussed further in the following chapter.

7 Discussion of results

The main results of the study, i.e. the new set of LPO determinants that hinder or support a successful implementation of innovations in disaster management to increase resilience, accompanied by a description of each determinant and its influence, has been presented in subchapter 6.3. In more detail, the research question and its "sub questions" (see subchapter 1.3) are answered as follows:

Answering the research questions

First sub question "*Which LPO determinants can be identified based on previous studies, and how can their influence be described? How can the identified LPO determinants be categorized?"*: Based on an analysis of literature on innovation in the public and the private sector, a set of 10 determinants which address laws and policies have been identified and categorized under "Information sharing", "Cooperation & knowledge sharing", "Protection of employees & of the organization", and "External incentives" (see chapter 4). In addition, 16 determinants addressing organizational factors have been identified and categorized under "Staff and work process", "Intra- and interorganizational cooperation & communication", "Innovation culture", and "Compatibility of innovation-specific characteristics" (ibid.). This has considered the characteristic conditions in disaster management organizations and reflected upon the special context of the disaster management sector. A description of each determinant is included in chapter 4.

Second sub question "*Which LPO determinants can be identified by analyzing recent implementations of innovations in disaster management to increase resilience in the EU (using expert interviews)? In how far does this correspond to results obtained by literature-based analysis?"*: The results of an analysis of which LPO determinants have been relevant for each of the selected innovation implementations, based on expert interviews, are presented in chapter 5. It includes an analysis of how the determinants identified in chapter 4 have been relevant for the selected innovation implementations, as well as additional aspects. These results have been consolidated and further evaluated in chapter 6, showing, for example, that the predefined determinant *Commitment of individuals* was highly relevant in all examples. In addition, some aspects have been identified that essentially influence the success of an innovation implementation process. For example, *Time* available for improving and adapting an innovation is an additional determinant derived from the expert interviews. In total, five determinants have been added to the set of predefined determinants. Furthermore, a few aspects did not lead to new determinants, but to adapted versions of three predefined determinants, such as institutionalized networks, which led to the adapted determinant

Interorganizational cooperation & networks. Two predefined determinants could not be confirmed in the interviews: *Regulation on protection of intellectual property rights* as well as *Employment protection regulations*. However, this does not necessarily prove that they are irrelevant, thus they have not been removed from the set of determinants.

Third sub question "*Which of the identified LPO are innovation specific, and which ones can be transferred to other innovations in disaster management? How?"*: A few aspects identified in the expert interviews seem to be solution specific, see subchapter 6.2. For example, the *Efficiency principle* can be relevant for envisaged innovations in control centers for rescue services, but not elsewhere. All identified "determinants" can be relevant for different innovations in disaster management. Table 31 and Table 32, which encompass the new set of determinants, also include descriptions of the types of innovations for which the determinants could be relevant.

Fourth sub question *"What are the similarities and differences regarding different types of innovation?":* Observed differences in the effects of each determinant on the example innovation implementations according to the different types of innovation (distinguishing between product and organizational innovations as well as between fundamentally new innovation, innovation improving existing product/process, and innovation imitating existing products) are described in subchapter 6.1. Table 31 and Table 32 include information on innovation types for which an effect of a determinant can be expected. General tendencies explored in subchapter 6.3 include, e.g., that innovation implementations tend to be more strongly influenced by determinants if the innovation is a product innovation, and if it is a fundamentally new innovation.

The answers to the sub questions finally lead to an answer to the overall research question "*Which LPO determinants hinder or support a successful implementation of innovations in disaster management to increase resilience, and how?"*: This is mainly answered in the overviews of Table 31 and Table 32, and related descriptions in chapter 6. In particular, *Commitment of individuals, Available financial resources,* and *Time* have been identified to be most crucial determinants for successfully implementing innovations in disaster management. In addition, fundamentally new product innovations are more strongly dependent on the identified determinants than other types of innovation.

Reflecting on the applied methodology

The literature-based analysis was challenged by the study's topic being located at the intersection of several research fields. Literature from various disciplines, such as economics, innovation management, (organizational) resilience, organizational change management, disaster risk management, security, policy and law, had to be assessed and evaluated. This was solved by mainly extracting innovation determinants that had been identified in previous studies, and analyzing literature related to the identified topics. Finally, the determinants were transferred to disaster management supported by literature covering specific characteristics of

the disaster management sector and its organizations. In this way, it has been possible to achieve a solid knowledge base derived from literature and applied to disaster management.

Expert interviews served to analyze, complement, verify or refute the results from the literature-based analysis, since the topic is not yet sufficiently covered in the literature. The methodology of expert interviews enabled a deeper analysis of real cases, i.e., of innovations that have recently been implemented in disaster management. Identifying suitable cases was not trivial, since there is as yet no database of innovations in disaster management. Other sources, including related databases such as a European tender platform (TED), a platform providing results of EU funded activities (CORDIS), or a platform for innovations stemming from EU projects (Innovation Radar) did not reveal the required examples either. Finally, it was possible to discover suitable examples for the study by investigating and participating in events (conferences, fairs) that specifically included presentations of innovations as well as by making direct contact to disaster management organizations.

Deploying the qualitative approach of using expert interviews cannot claim to produce representative results. It was also not possible to upscale results to a whole country, i.e., the results that were identified cannot be seen to be representative for the countries of the selected examples, i.e., Germany, Austria, and the Netherlands. However, it has allowed the hypotheses on determinants from the literature-based analysis to be supported or refuted. The results indicated whether the relevance of determinants as identified in the literature analysis is plausible or not, showed which determinant is likely to influence which type of innovations, and also identified additional aspects. An alternative would have been to conduct a broad survey addressing a large number of organizations, including organizations that had not implemented any innovations recently. In this way, a high number of cases could have been achieved, which would also have allowed a statistical analysis of the results, in order to identify relationships and dependencies among the determinants. However, such an approach would not have been able to take the opportunity to carry out in-depth analyses, or of additional questions coming up during an interview, or the possibility of concentrating on specific examples for concrete and stringent results. It would not have been possible to collect all essential information, which was required in order to adequately explain the role of each determinant. Instead of generalizing the results based on statistics, an investigation was carried out on a case by case basis, to see the extent to which findings can be transferred to other cases, e.g., regarding different types of innovations. This resulted in new determinants which are transferable to other innovation implementation processes, as well as aspects considered to be solution specific.

While representative interviews were impossible, the selection of interviewees was decisive. A broad survey would have randomly addressed representatives of organizations. For the expert interviews, it was possible to select interviewees based on several criteria, including the intense involvement in an implementation process. In addition, different roles were covered, i.e., users – at operative and management levels – as well as suppliers of innovations. The

execution of the interviews then depended on the availability and willingness of the experts to participate in an interview. The level of interest appeared to be high among the experts and organizations, and almost all experts who were asked were prepared to participate. One envisaged example innovation had to be excluded because the supplier feared any disclosure of knowledge could have a negative impact on their competitive advantage. In very few cases, an interviewee was reluctant to answer a question, e.g., on internal communication issues. This has been considered in the evaluation.

Focusing on specific innovation examples allowed an in-depth investigation to be carried out, however, since no interviews were conducted with organizations that did not implement any innovation, it is possible that examples have been missed where hindering determinants appeared very clear. So, it is possible that some barriers have not been documented. Nevertheless, the analysis of example innovation implementations explicitly included supporting as well as hindering factors. Further, if an interviewee did not consider a specific determinant to have had a strong influence, it is still possible that this determinant actually did have a strong influence. For example, the availability of the required budget might appear as an obvious crucial determinant if someone has experienced similar cases where a required budget was not available. But if an interviewee had not experienced similar cases with a lack of budget, the availability of budget might not appear to be a particularly determining factor to the interviewee. Such inevitable biases within expert interviews can only be absorbed by conducting several interviews, and by considering this during evaluation. Similarly, it is also possible that specific aspects have not been identified, because they seem self-evident in the specific context. But compared to other innovation implementations they might not be self-evident at all. For example, when the innovation (G) "Warning system", developed and applied in Germany over many years, was implemented in Austria based on a license agreement with Germany, experience and lessons learned from Germany were shared with Austria. Due to their close collaboration, this exchange of experience seemed obvious. In contrast, in other cases, no comparable case existed, or, information was missing on who would own similar experience (as in the case of the drones). Moreover, by focusing on specific innovation examples in the interviews, the difference between the general *Available financial resources* and the specific *Costs* of an innovation became partly blurred, because the availability of financial resources was referred to the specific case, and not answered on a general basis.

The literature-based analysis revealed that the direction of influence of the determinants *Regulation on protection of intellectual property rights, Existence and use of standards*, *Employment protection regulations, Liability regulation*, and *Available financial resources* can differ, i.e., have positive or negative effects on an innovation implementation process. The relevance of *Regulation on protection of intellectual property rights* and *Employment protection regulations* could not be confirmed at all by results from the expert interviews, as mentioned above. For the other three determinants, the expert interviews confirmed only one direction each, which means that the question remains open as to whether the other direction can also occur in innovation implementation processes in disaster management, and under which conditions.

Dependencies between some of the determinants can be identified. For example, general budget constraints in an organization increase the probability that it is difficult to cover specific costs of a considered innovation. However, the determinants all differ in their core parts, excluding redundancies. A high number of cases based on a broad survey would have allowed these dependencies to be quantified through factor or cluster analysis. However, this would have been at the expense of the essential advantages of the expert interviews as explained above.

The determinants and their relevance may vary depending on different contexts, in addition to the sector of interest, and in addition to public vs. private organizations. Differences depending on the type of innovation have been investigated in this study. Differences by country or even region are also possible, due to different political set-ups, regulations, or cultural values. Even though the example innovations stem from different countries (Germany, the Netherlands, Austria), and even though regulations and policies have been included in the analysis, results cannot be generalized for specific countries. One determinant has been defined that is specifically related to the federal political system of a country. However, it is possible that there are specific issues related to other political systems that are not documented in the results of this study.

It is also important to consider the focus on the implementation phase of an innovation process in this study. Other phases have explicitly not been excluded, due to their strong interdependency. However, the results might look different when focusing on, e.g., ideation or development of an innovation. The reason for focusing on the implementation phase in this study was the observation that for example some technical developments such as digitization, widely implemented in other sectors, have hardly been implemented in the field of disaster management.

It should also be noted that the analysis of innovation determinants led to descriptions of the way a determinant influences the success of an innovation implementation, but there is no measure to quantify the contribution of a determinant to "success". The main reason is that there is no benchmark indicating the success/nonsuccess of an innovation implementation. Also, the contribution that a successful innovation implementation might have is not quantified. Instead, the study follows the assumption that any of the considered innovation implementations increases the efficiency of the organizations' work, and thereby society's resilience.

Finally, regarding the effect on the resilience of a society, the following should be noted: determinants have been analyzed that influence the implementation of innovations in disaster management and thereby the resilience of a society. As explained in subchapter 1.1.1, it is assumed that any improvement in disaster management also enhances resilience. However, there might be innovations other than those implemented in disaster management organizations that possibly strengthen resilience (e.g. new approaches to reduce

vulnerabilities of a society, or strategies in land-use planning to decrease disaster risk). These innovations have not been considered in this study.

Findings in comparison to selected previous work

Within innovation management literature, Hadjimanolis (2003), for example, has described general barriers to innovation (in the private sector). These barriers are part of the findings that have been extracted from literature, and transferred to the disaster management sector in this study. Addressing the public sector, the OECD (2017) has developed recommendations for governments that strive to foster innovation in the public sector. The present study took a broader view on possible determinants, while focusing on disaster management. The study has further used results of comprehensive literature analyses on public sector innovation (Vries et al. 2016; Vries et al. 2018; Cinar et al. 2019), by transferring the results to the disaster management sector and focusing on innovation implementation. In this regard, the study extracted and adapted results of these reviews, and applied and further evaluated them in a specific context.

The results also complement findings of the research area of technology assessment *(Technikfolgenabschätzung)*, taking on a complementary point of view: While technology assessments reflect possible positive and negative impacts of technology, the determinants as identified in this study reflect conditions that positively or negatively influence the applicability (i.e., implementation) of technology. In this regard, they also complement identified requirements for the application of technology in disaster risk reduction, as identified (but not examined in depth) in a study commissioned by the UNISDR (Basher 2013). In addition, by directly addressing laws and policies that could influence an innovation implementation, the present study complements findings on laws and regulation frameworks for disaster risk reduction, which have been derived from an analysis by a joint initiative of the International Federation of Red Cross and Red Crescent Societies (IFRC) and the United Nations Development Programme (UNDP) that focus on general disaster risk reduction approaches and strategies (UNDP and IFRC 2014).

Moreover, results of this study complement previous studies that have analyzed, for example, factors of good risk management or good risk governance on a higher level (e.g. those by van Asselt and Renn (2011), Hutter (2005), Aven (2011), Rosa et al. (2014), or Hood et al. (2004)). While they identified principles of good risk governance, Aven and Renn (2018) also note that in practical situations, these principles are often not easily implemented. Results of the study at hand can contribute on a more detailed level to reveal underlying factors that influence the feasibility of the principles of good risk governance. For example, the principle of good governance "openness and transparency" is related to those determinants that belong to the group "Intra- and interorganizational cooperation and communication". The results also detail some factors that influence the required balance between efficiency and resilience (see e.g. Renn 2016). An obvious example is the determinant *Costs* of an innovation, which can hinder the solution from being "efficient", even though it would possibly enhance resilience.

Studies such as those by Murphy and Greenhalgh (2018), Weidinger et al. (2018), Allaway (2010), Lum et al. (2017), and Martí (2011) describe specific characteristics of disaster management organizations. The identified innovation determinants in this study complement them by adding information on conditions that shape the ability to change and to innovate.

8 Recommendations & Outlook

The results of the study can be used to derive recommendations for further research as well as practical implications for disaster management organizations and at higher political levels. In addition, the study's results can be relevant for current international approaches. These considerations are described in this final chapter.

Recommendations

Recommendations for further research

Based on the results of this study, or complementing them, it is recommended to conduct future research on the following:

- Further specify variations in the relevance of innovation determinants among different countries and/or political systems.
- Investigate innovation determinants in disaster management focusing on phases of an innovation process other than implementation, e.g. ideation or development.
- Further detail an assessment of the determinants *Existence and use of standards*, *Liability regulation*, and *Available financial resources.* While literature suggests that an influence of these determinants can be both supportive and hindering, the expert interviews only confirmed one direction of influence. It could thus be analyzed, if and under which conditions, the other direction of influence can be expected.
- Analyze determinants of innovation implementation in other fields of resilience, such as prevention and reduction of disaster risk (e.g. regarding new prevention strategies, land-use planning, or measures for exposure reduction); complementing those analyzed for disaster management in this study.

Following the results as presented in chapter 6, recommendations regarding practical implications can be derived, e.g. for organizations planning to implement an innovation, or for decisionmakers who wish to support innovation processes in disaster management. The latter can be part of the organization under consideration, or a related government organization. In particular, the following recommendations are derived:

Recommendations regarding practical implications

- Consider that *Commitment of individuals* is decisive for successfully implementing an innovation, including commitment at management level, of other staff, as well as external individuals. Possible ways to address this issue is persuasive communication,

but also a staffing policy that considers the importance of committed individuals for innovation processes.

- Allow an innovation to be implemented over *Time*, avoid demanding a quick and abrupt implementation process. Do not expect an innovation to work perfectly right away, but allow and support learning processes and continuous adaptations. Possibly accept flexibility for deadlines.
- Consider that the *Available financial resources* are decisive in many cases for innovative progress in disaster management. This should be reflected in upper level strategies on innovative ecosystems, or on enhancing disaster management capabilities.
- For an envisaged innovation implementation, check the relevance of other determinants as well, depending on the type of the specific innovation, see Table 31 and Table 32.
- Support the establishment of institutionalized networks. As the determinant *Interorganizational cooperation & networks* shows, institutionalized networks can be strongly supportive for innovative actions. The approach of "European Innovation Ecosystems" in the context of Horizon Europe (European Union 2020a) for example, which aims to bring stakeholders together, seems to be promising in this context.
- Enhance sharing knowledge and lessons learned on innovation implementations in disaster management. Approaches to identify examples of implemented innovations in disaster management (see subchapter 5.1.1) revealed a lack in this regard. An adequate realization of current approaches such as the Innovation Radar of the European Commission, the International Forum to Advance First Responder Innovation (IFAFRI), or the European Innovation Council (EIC), see below, can help to close this gap.

While these recommendations already include references to international approaches, they are further elaborated in the following.

Results in the context of international approaches

By unravelling innovation determinants in disaster management, the results of the study offer opportunities to support successful innovation implementations, and thereby create strengthened and more efficient disaster management to increase the resilience of a society. This can contribute to the overall ambition of the Sendai Framework for Disaster Risk Reduction (UNISDR 2015), especially the second priority for action "Strengthening disaster risk governance to manage disaster risk". To increase, amongst other things, preparedness for disaster response, and thus strengthen resilience, the framework asks for the implementation of measures, including technological, legal and political measures. It also emphasizes the need for investments in, and support for innovation and technology. In addition, when implementing activities, the framework explicitly requests that "respective capacities and capabilities, in line with national laws and regulations" (UNISDR 2015, p. 14) are taken into consideration. Thus, results of the study can contribute to addressing these requests to strengthen innovation and consider context factors. This is also true for respective approaches

on implementing the Sendai Framework: The "Making Cities Resilient" campaign of the UNDRR, which strives to support the implementation of the Sendai Framework, and, amongst other things, aims to "upgrade the city's emergency response services" in the context of the goal to "ensure effective disaster response" (UNDRR 2019c). While the current campaign is due to end in 2020, the envisaged successor also includes a strategic objective to "increase city capacities to implement disaster risk reduction strategies and reduce disaster risks" (UNDRR 2019b).

The study's topic and results are also in line with approaches of the International Risk Governance Center (IRGC). The IRGC, amongst others, addresses scientific and technical opportunities that should be supported by appropriate policy and regulatory strategies, and aims to provide evidence-based recommendations for risk governance. The "IRGC Risk Governance Framework" has been developed to provide guidance for the use of risk governance concepts. In addition to a core risk governance process, the framework emphasizes the relevance of the broader context including political cultures, governmental and regulatory aspects, as well as organizational capacities (IRGC 2017). The study's findings on laws, policies, and organizational determinants can therefore contribute to an implementation of the IRGC Risk Governance Framework.

Results of the study can also complement approaches of the International Forum to Advance First Responder Innovation (IFAFRI), which is an organization of international members aiming to enhance innovative technology for first responders. IFAFRI's objectives include a definition of capability gaps, strengthening international collaboration on innovative research and development of initiatives and solutions, as well as guiding industry to make innovative technology available and affordable (IFAFRI 2020). While respective initiatives address most relevant pre-conditions to make innovative solutions available for disaster management, results of the study can help to overcome barriers to their actual implementation.

On EU level (each of the innovation examples analyzed in this study has been implemented in an EU country), there are comprehensive initiatives to enhance innovation in the security domain. In addition to funding security research, objectives of the initiatives include aiming to overcome the fragmentation of the EU security markets for security technologies, and to reduce the gap between research and market (European Union 2020b). The market fragmentation has also been considered in this study (see subchapter 2.2), and results of the study can contribute to reducing the gap between research and market, since barriers and enablers to innovation implementation essentially influence this gap. The upcoming EU research and innovation framework "Horizon Europe", to be launched in January 2021, also encompasses new instruments to nurture innovation, such as the "European Innovation Council" (EIC) that is designed to foster breakthrough innovations (European Union 2020a). Finally, enhancing innovation activities (by means of a better understanding of supporting and hindering factors) can also strengthen disaster management capabilities available for

international assistance, e.g., through the EU Civil Protection Mechanism, including the RescEU reserve (see subchapter 2.1).

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Annex: Interview guideline

QUESTIONS FOR THE INTERVIEW ON INNOVATION DETERMINANTS

1) Can you please tell me about *the overall implementation process* of [the example solution] in [your organization]? (starting from the first idea)

2) Can you please tell me about *your personal experience* with the implementation process?

3) From your point of view, *which factors had an influence* on the way or the velocity of the implementation? (e.g. regulations, structures, working processes…)

4) Can you please *elaborate on the different factors* mentioned under 3)?

   (Possibly, the interviewer will ask about factors that have not already been mentioned.)

5) Summarizing the different influencing factors, *how strong* was the influence of each factor, from your point of view?

6) Where do you see *possibilities to improve* the situation for future innovations?

7) Is there *anything else* that you would like to mention/ that seems relevant from your point of view?

Thank you!

Short CV of the author

For data protection reasons, the curriculum vitae is not included in the online version.