Involving Public Transport Companies in Disaster Management During a Blackout – A Feasibility Study

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Lund 2023

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Number of pages: 55
Illustrations: 1

Keywords
blackout, disaster management authority, public transport company, cooperation concept, feasibility study, buses, disaster management structures in Germany,

Abstract
This thesis explores how a blackout can be better managed using existing public transport company resources. The study addresses three research questions by assessing the feasibility of possible cooperation between local public transport companies and disaster management authorities during a blackout. Data from 14 interviews with experts from disaster management authorities, public transport companies, and the scientific community were conducted to answer the research questions. Supplementary information was obtained from literature research to carry out a context-specific feasibility study. The first research question aimed to determine what challenges the organizations will face during a blackout. To answer the second research question, the 5 categories of technical, organization, finance, legal and safety matters, and willingness to participate were reflected to determine which challenges must be overcome to implement a cooperation concept. It was found that the implementation of cooperation is generally feasible and accepted. However, there are some contexts where specific challenges need to be overcome, such as communication in rural areas or the technical implementation of increasing bus fleet electrification. Finally, with the input of the experts, a cooperation concept was suggested as an answer to the third research question. The proposed concept contains flexible modules that the authorities and public transport companies can introduce per their specific requirements and contextual needs. Each module encompasses a particular resource (diesel, bus drivers, stops, and buses) and outlines the necessary prerequisites for successful implementation. In addition to the concept, recommendations for the next steps are given to implement such a concept successfully.

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Summary

Many German counties and district-free cities are currently preparing for long-lasting, nationwide power failures, also known as blackouts. As the responsible authorities, disaster management officials are preparing for a widespread failure of communications, food supply, health care, and other critical infrastructures. This thesis examines how the damage induced by a blackout can be better reduced with already existing resources. More specifically, the resources of the local public transport companies are considered. The original idea of the study is that public transport companies support the disaster management authorities in a blackout by taking over different tasks and making their resources available. In the first step of the thesis, research question one investigates which challenges public transport companies and disaster management authorities face during a blackout and how the organizations' collaboration is hitherto. The second research question examines the challenges that must be overcome to realize such a cooperation concept. The last research question explores what a possible cooperation concept might look like implementing buses/ public transport companies in disaster management to support a city/county in coping with a blackout situation.

The above questions are answered by applying the feasibility study for regional projects, according to the framework from Weiß (2003). The general feasibility of possible cooperation is assessed through the basis, preparatory, and main investigation. In the main investigation, the areas of technical standards, organizational requirements, legal framework, economic viability, and public and organizational acceptance are considered. Data from a literature search is used for the implementation, but mainly the answers from expert interviews are used. A total of 14 interviews were conducted with 18 interview partners from disaster management authorities, transport companies, and experts from the scientific community.

The main challenges that disaster management authorities and public transport companies face during a blackout are identified in the basis investigation. The authorities face difficulties informing the population, alerting their staff, and having enough fuel available. The transport companies have fuel and a close relationship with the population but depend on disaster management information and instructions. Cooperation between the two is therefore essential. The following preparatory investigation shows that some disaster

management authorities already have concrete agreements with the public transport companies for blackout scenarios, while others have emergency plans but no specific agreements. However, experience has been gained in cooperation, such as transport companies supporting disaster management during evacuations, refugee crises, and the COVID-19 pandemic. Some experts have also gained experience through joint staff work. Overall, the findings suggest that cooperation is necessary and beneficial for managing blackouts. Based on this finding, the main investigation is conducted to determine which challenges need to be overcome to feasibly implement such a cooperation concept.

The main investigation found that public transport companies can implement communication during blackouts with emergency-powered communication systems or in medium-sized cities. However, it is challenging in rural areas due to the many actors and area size. Technical aspects such as fuel supplies and available buses are not currently a problem but may become one by 2030 as the bus fleet becomes increasingly electrified. Personnel availability and tailored crisis timetables are crucial. Financing is a hurdle for non-subsidiary traffic companies and in rural settings. Experts agree about the high willingness to participate and acceptance of the concept and the importance of pre-arrangements for successful cooperation. The feasibility study provides valuable insights for implementation, and experts have provided suggestions for improvement. Overall, the study highlights the importance of cooperation between public transport companies and disaster management authorities during blackouts.

In the last step, a proposal was made on how a well-structured concept for cooperation could look. For this purpose, the existing resources, and the corresponding functions that these resources can take on were incorporated into a modular and scalable system. It is important to note that although this concept is relatively generalizable, certain preconditions must always be fulfilled, and its application does not necessarily make sense in every context. Additionally, to the concept, suggestions for the following actions are provided to implement such a concept properly.

Contents

1. Introduction

It cannot be ruled out that a blackout will occur in Germany, even if this scenario is rather unlikely. A blackout would result in losing many critical infrastructures and even vital services (Mayer, 2017). A blackout is defined by the German Federal Office of Civil Protection and Disaster Assistance (BBK) as a long-lasting power outage that affects several German states or even the whole of Europe (Mayer, 2017). Such a blackout can occur if there are severe interruptions in the grid control processes due to technical or human failure, criminal attacks, or severe natural events (Petermann et al., 2011). The risk of a blackout tends to increase due to the growing geographical and technical interdependencies in the power grid and the increasing use of energy sources that feed irregularly into the grid, such as wind and solar power. Besides, extreme weather events will damage the infrastructure more frequently due to climate change (ibid.). Recent geopolitical situations also highlight the vulnerability of the power grid. During a pandemic, power grid operators might experience critical personnel absence (ibid.). On the other hand, the Russia-Ukraine war increased concerns about power outages, as the disruption of the Nord Stream pipeline eliminated gas as a significant raw material for Germany's energy supply. At the same time, fears of terrorist attacks on the power grid with political motivations are raised (Halser & Paraschiv, 2022).

A long-lasting power blackout has numerous consequences, such as the loss of communication and information systems, an interruption of food and water supply, a failure of heating systems, and reduced health care (Birkmann et al., 2010). The possibly disastrous outcome of a blackout, the topic's actuality, and the growing unrest among the population are causing many German counties and cities to deal with the blackout scenario explicitly. In Germany, the counties, as the lower disaster control authority, are responsible for disaster control and initiating appropriate preparedness and response measures (Petermann et al., 2011).

In the course of a technical impact assessment commissioned by the German Government, Petermann et al. (2011, p. 239) dealt with the risk of blackouts in detail. They concluded that further efforts are required at all levels to optimize the capacity of the national disaster management system in a targeted manner. The importance and topicality of blackout

preparedness is also reflected in the media and the increasing number of publications of the responsible authorities for disaster control. Mainly the German Federal Office of Civil Protection and Disaster Assistance regularly publishes much-cited guidelines on how the population, companies and authorities or the critical infrastructure sectors can prepare for a blackout. For risk analyses, the blackout scenario is usually considered separate from other scenarios because it is difficult to determine the probability of occurrence for this risk (Henneaux et al., 2012). Nevertheless, this scenario was frequently considered even before the gas shortage occurred, as a blackout reflects the interdependencies of the critical infrastructures very well (Petermann et al., 2011).

Good preparation for a blackout means, among other things, that redundant means of communication are available, organizational structures such as crisis teams have been created, logistics concepts exist, and the population has been informed and educated (Hiete et al., 2010; Rhein, n.d.). All these preparatory measures are also helpful for other crises, such as the failure of another critical infrastructure or natural disasters like floods. In the case of the flood situation in the Ahr valley in July 2021, for example, communication was limited for days, there was no continuous power supply, and due to the problematic accessibility, external help was hardly possible in the first hours (Koks et al., 2021). Blackout preparation, next to the flood preparations, would have helped reduce the disaster's impact to some extent.

Therefore, good blackout preparedness brings many advantages but also hurdles for cities and counties. Disaster management and preventive measures are expensive, and it is hoped that the investments will never be needed in the first place (Mahdavian et al., 2020). Consequently, it is often criticized that too little has been invested in blackout prevention in Germany so far (Diekmann, 2022). Often there is a lack of human or financial resources, or the responsibilities are unclear. This is where the research problem of this thesis is seen. How can a blackout be managed better with already existing resources? Complex situations sometimes require new and unconventional solutions. Especially those innovative ideas should be given more attention and implemented if suitable.

One of these unconventional solutions could be implementing local public transport companies in disaster management. Transport companies usually offer many resources like personnel, vehicles, fuel, means of communication, and local knowledge. The transport companies could be used in the event of a blackout through fuel-powered local transport

vehicles like buses, to distribute information, take and forward emergency calls from the population or transport people and goods. These functions could help to reduce the damage because the population gets information about the nearest medical help for example, and people who work in critical infrastructure can reach their workplace.

The term public transport company refers to companies that provide public transport services in a city or county. These companies usually offer transportation of passengers via different means of transport. However, the focus of this work was on companies that operate buses. The respective cities and counties, which are also the contracting authorities, are responsible for local public transport in Germany (DB Regio, n.d.). Formally these transport companies are run under a private legal form and are either communally or privately owned. Here, communal ownership is the standard and private ownership is the exception (ibid.).

1.1 Purpose and Research Questions

The purpose of the master's thesis is to examine the current state of cooperation between transport companies and disaster management authorities and analyze the challenges the institutions will face in case of a blackout. Furthermore, an iterative process will be used to develop a concept that can be generalized for all German cities and counties, describing how public transport companies can support disaster management authorities in a blackout by taking over different tasks to relieve the disaster management authorities. It should also be examined whether it is feasible to implement such a concept regarding technical standards, organizational demands, legal frame, economic viability, and public and organizational acceptance.

More specifically, this thesis aims to answer the following questions:

Research Question 1: What challenges do transport companies and disaster management authorities face during a blackout, and how is the collaboration between the organizations hitherto?

Research Question 2: What challenges must be overcome to implement a cooperation concept in practice feasibly?

Research Question 3: How could a possible concept look like implementing buses/transport companies in disaster management to support a city/county cope with a blackout situation?

1.2 Current Research and Practice

Numerous examples show how disaster management authorities in German counties and cities already cooperate with public transport companies. For example, in the event of a crisis, transport companies make their fuel depot available to disaster control vehicles (Arndt, 2019) or support the evacuation of people in the event of bomb disposals, forest fires, or floods (Bezirksamt Mitte, 2022). In some cities, warnings are also displayed on digital displays at bus stops and on buses and trains, which can be automatically fed with information via satellites (IM BW, n.d.). However, these examples can only be applied to the blackout scenario to a limited extent. In general, the disaster management authorities provide undetailed information about their cooperation, presumably also for security reasons. More detailed insights through the data collection of this thesis can be found in chapter 4.2.

In Germany, there have been and still are several research projects on blackouts, which deal with different aspects of power blackout preparedness and management. One example is the project "EmergenCity," led by the LOEWE Centre, which aims to protect the digital infrastructure of cities from the effects of disasters by making them resilient (TU Darmstadt, 2023). Another project that focuses on improving crisis response is the project "Katastrophenschutz-Leuchttürme" (Disaster Protection Lighthouses) (Ohder et al., 2015; OSCE, 2016). These emergency-powered lighthouses are well-known public buildings. They will serve as a focal point and communication center in emergencies such as blackouts and facilitate coordination between relief organizations. The primary function of the lighthouses is to provide information, but they can also provide medical help, for example. Although there are many research projects on blackouts, no specific projects were found that deal with the cooperation of transport companies and disaster management authorities.

1.3 Thesis Structure

This chapter has addressed the importance of good blackout preparedness, the research problem, and the aim of the master's thesis. Furthermore, current research and practice were discussed. Chapter 2 explains the definitions of essential concepts and frameworks used in this thesis in detail, so the reader and author share a consistent understanding of these concepts. Chapter 3 deals with the methods used in this work for data collection and data analysis. The limitations of the methods are also discussed. Chapter 4 presents and

discusses the results in the form of a feasibility study. Chapter 5 concludes with answers to the research questions and suggestions for the next steps to implement a cooperation concept into a specific context and future research priorities.

2. Conceptual Framework

The introduction presented the blackout scenario as a long-lasting, interregional scenario. The causes and possible consequences were also discussed. This chapter will now introduce the concept of critical infrastructures and disaster management structures in Germany. Furthermore, the framework "Feasibility Study," used in this thesis, will be introduced.

2.1 Critical Infrastructures

Functioning infrastructures are fundamentally important for an intact society (Witte et al., 2021). The following sectors have emerged as particularly "critical" infrastructures: Energy, information technology and telecommunications, transport and traffic, health, water, food, finance and insurance, state and administration, as well as media and culture (BBK, 2021). Critical infrastructures are defined as organizations or facilities with important significance for the state's community, the failure or impairment of which would result in ongoing supply shortages, significant disruptions to public security, or other drastic consequences (ibid.). What is special about these infrastructures is that they influence each other and are often interdependent (Witte et al., 2021). Consequently, it makes sense to view critical infrastructures as complex systems (ibid.).

Transport and traffic are also critical infrastructures that would be affected during a blackout. Independent of the idea of this thesis to integrate public transport companies into disaster management, it is therefore important to maintain the function of transport companies as far as possible.

2.2 Disaster Management Structures in Germany

"Disaster management" is the process of preparing for, responding to, and recovering from natural or man-made disasters (UNDRR, n.d.). It involves coordinated efforts by government agencies, emergency responders, non-governmental organizations, and individuals to mitigate the impact of disasters on people, property, and the environment (Coppola, 2011). Disaster management aims to reduce the risk of harm and ensure an effective and efficient response to disasters. This can include activities such as risk assessment and planning, public education and awareness, emergency preparedness measures, search and rescue operations, medical care and treatment, and rebuilding and recovery efforts (ibid.). Disaster

management can help communities and societies become more resilient and better able to cope with the impact of disasters (ibid.).

In Germany, disaster management (Katastrophenschutz) and civil protection (Zivilschutz) are related concepts but have slightly different meanings and functions. In many English-speaking countries, there is no differentiation between those terms, so both are translated as civil protection.

"Katastrophenschutz" refers to the measures and activities taken to prevent or mitigate the impact of natural or man-made disasters, such as floods, storms, fires, or terrorist attacks (BBK, n.d.-b). It is a comprehensive term encompassing all aspects of disaster management, including prevention, preparedness, response, and recovery (ibid.). The responsibility for disaster management lies primarily with the 16 states as the higher disaster management authority. However, the operational implementation of hazard defense lies with the lower disaster management authority and, thus, with counties and district-free cities (ibid.). The federal government has no direct responsibility for disaster management but can assist.

"Zivilschutz," on the other hand, refers specifically to the measures and activities taken to protect the civilian population in the event of a national emergency or war (ibid.). This can include measures such as air raid protection, evacuation plans, and emergency shelters. Zivilschutz is regulated by the Zivilschutzgesetz (Civil Protection Act) and is primarily the responsibility of the federal government (ibid.).

Consequently, blackout management is a disaster management task (Katastrophenschutz) and is accordingly regulated by the 16 states. Due to the principle of federalism, the states all have different disaster control laws, standards, and working methods (Geier, 2021). In addition, the implementation of disaster management is delegated even further down so that each county and city as an administrative unit prepares differently for a blackout (ibid.). While some municipalities have been dealing with the issue of blackouts for a long time and are already well prepared, others are still at the very beginning (NDR, 2022). In times of a crisis, disaster management authorities can use the resources of other authorities or even private companies if necessary, including transport companies, for example, for transporting emergency goods or evacuating people (BBK, n.d.-b).

In addition, Germany has the Federal Office of Civil Protection and Disaster Assistance (BBK), which coordinates disaster management and civil protection and provides support in

preparing for disasters. However, the BBK has the task of developing recommendations and guidelines for action and making them available to the responsible authorities (BBK, n.d.-a). These recommendations are intended to help the authorities respond quickly and effectively during a crisis (ibid.).

2.3 The Theory of Feasibility Studies

A feasibility study, which evaluates whether an idea is realizable under certain circumstances, is a practical method (Bause et al., 2014). The method feasibility study is a basis for deciding whether and how a project can be carried out (Angermeier, 2009). It examines possible solutions for a project with regard to their feasibility. Within the framework of a feasibility study, the approaches to a solution are analysed, risks are identified and prospects for success are assessed (ibid.). Typically, several criteria must be met for a project to be feasible. These criteria are presented in this chapter. The feasibility study method was chosen for this work because at the beginning there was an idea for a project which should be investigated in more detail. As cooperation between transport companies and disaster management can be implemented in different ways, the method is well suited to analyse different challenges and approaches. Furthermore, a feasibility study is a popular instrument to investigate project ideas in a practical way. Practical relevance was also important in this work so that the results could have an impact on potential practitioners.

Weiß (2003) has developed a model for feasibility studies for regional projects, which fits ideally into the setting of this thesis since the idea to be tested also represents a regional project. A feasibility study is classified as an ex-ante and summative evaluation. It aims to evaluate whether the idea is suitable for implementation or in which contextualization and specification it most fits (Venable et al., 2016). For the development of the model, Weiß (2003) analyzed ten standard models for feasibility studies and adjusted them to the application of regional projects. A feasibility study is particularly important if the project has a high degree of novelty, has little experience with this type of project, and has many different project stakeholders who may have different interests (ibid.). Furthermore, no known referential projects also argue for conducting a comprehensive and formalized feasibility analysis.

Novel regional projects only have a good chance of success if the project idea is not yet concretely defined at the time of the feasibility study (Weiß, 2003). So, first, a very brief and flexible project idea was formulated for this thesis, which will be presented in chapter 4, as the first step of the feasibility study. This project idea was then evaluated regarding the feasibility of the project. In Weiß (2003) model, there are several steps, each of which can lead to the cancellation of the project if the results are negative. Since the evaluated idea is only dealt with theoretically in the master's thesis and should not be implemented in a specific context, the work is continued, and the arising issues are discussed even in the case of a negative interim result.

In the particular application in the master's thesis, Weiß (2003, p. 23) model will be slightly simplified and follows the next steps after the project idea was formulated: Basis investigation, preparatory investigation, main investigation, and final report in the form of the concept (figure 1). Normally, the final report would only be a written summary of the results. In the context of this work, an additional concept is presented, which presents the results in a graphical way and represents a concrete proposal for cooperation. The basic investigation analyses the challenges and the framework conditions in order to find out whether the project is necessary at all. The preparatory investigation then analyses the market situation, referential projects and gathers additional information to learn from the experience already made. The subjects of the main investigation are willingness to participate and acceptance, organization, finance, legal and safety, and technology. These categories are the same as suggested by Weiß (2003). Only the safety part has been added. This part is assigned to the legal section, as safety regulations are usually based on laws, standards or other guidelines and rules. Other authors suggest the same main investigation subjects. Some are also considering scheduling, which is irrelevant in this analysis, as there is no specific context to be examined yet (Bause et al., 2014). Based on the investigations, a concept is then developed. When referring to the project idea, the unspecific idea that was there at the beginning is meant. The concept is then the product of the feasibility study in which all challenges have been considered.

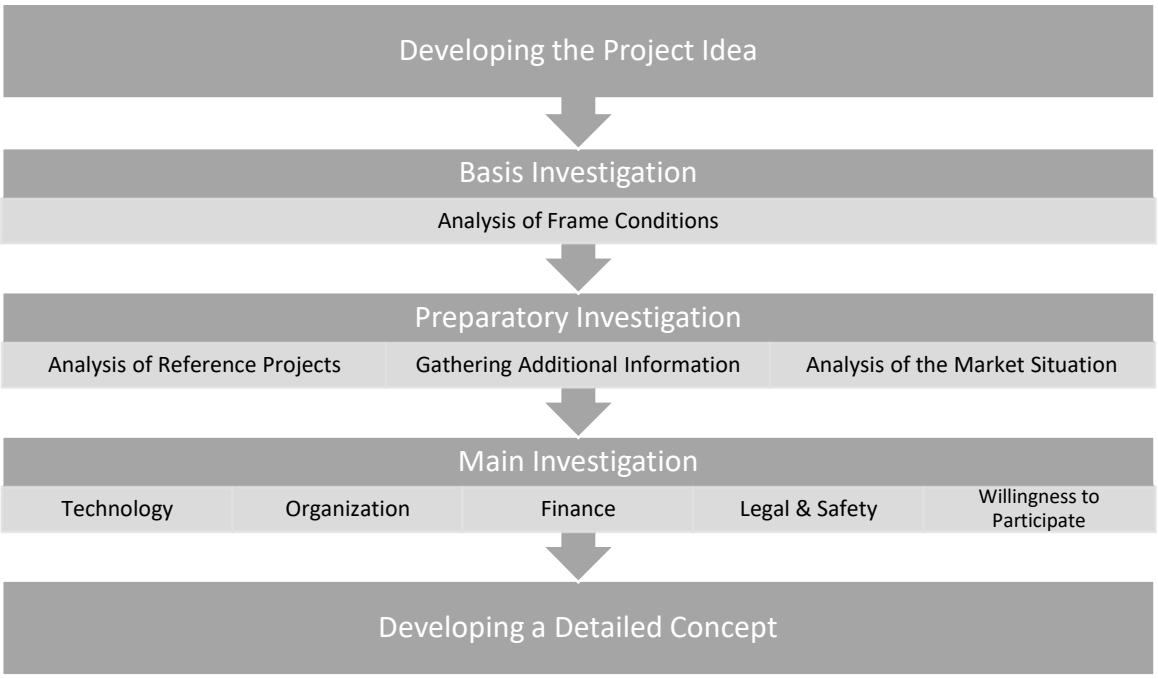

Figure 1: Iterative model to create concepts and test their feasibility. Adapted from Weiß (2003, p. 23)

The entire thesis is an iterative process, so new insights always lead to improving the project idea in order to develop the concept. Furthermore, the approach should be deductive so that the various alternatives to be examined are only developed during or as a result of the implementation-oriented feasibility study. For the main phase, Weiß (2003) recommends working with expert interviews to examine the five subjects of the main investigation by surveying key persons. The experts' suggestions, opinions, and restrictions should also be considered. All relevant actors in all areas shall contribute critique and their own ideas to develop a realistic cooperation concept. The expert interview should highly influence the finale project plan and be designed for suitable contexts. It is important to make the design process for the concept transparent and comprehensible to increase the credibility of the concept (Hevner, 2007).

3. Methodological Approach

In the master thesis, a qualitative approach was chosen to answer the research questions and to develop a generalizable concept of how transport companies can support disaster management authorities with their resources. Qualitative data collection is particularly suitable for investigating complex issues, illuminating details, and considering human factors (Creswell, 2013). The methods of literature research and expert interviews were chosen to conduct the feasibility study, according to Weiß (2003).

3.1 Literature Research

The Weiß (2003) framework contains three investigations. The main data collection was done through expert interviews. Nevertheless, relevant information was also collected through literature and online research for all three investigations. This research also generated the necessary content-related basis for developing the initial project idea (ibid.). The main focus of the research was to find out about reference projects, the concept's relevance, and other information such as laws that could influence the concept (ibid.). Furthermore, the experts' statements were partly verified by literature research.

Even though the literature research was intensive, the influence on the thesis was limited, as not much material was found on existing and reference projects. In addition to scientific papers, much information was obtained from publications of the counties and cities, online newspaper articles, and publications of the BBK, as the responsible authority. The literature was searched using standard search engines such as LUBSearch, Google Scholar or Research Gate. In addition, the BBK's specialist information centre was searched. A small amount of literature was referred to by the experts interviewed. In addition, the focus of the interviews also determined the attention of the literature search to certain aspects. Due to the iterative character of the master thesis, the results of the conducted expert interviews partly influenced the literature research focus. However, the interviews were also influenced by the research results and the gaps found in the literature research.

3.2 Experts Interviews

The primary data collection method was interviews with experts, as Weiß (2003) recommends. The main objective of the interviews is to analyze the five subjects of the main investigation of the feasibility study and to evaluate possible challenges and solutions.

Expert interviews aim to gain and explore data about a specific topic and to highlight human factors or organizational conflicts (Döringer, 2021). According to Döringer (2011, p.1), “experts are considered knowledgeable of a particular subject and are identified by virtue of their specific knowledge, their community position, or their status.” In total, 14 interviews were conducted with 18 interview partners. Six interviews were conducted with five different public transport companies (PT1-5). With one company, two interviews were conducted but with experts from different fields (PT1A and PT1B). Furthermore, five disaster management authorities (DM1-5) and three research experts (RE1-3) were interviewed. The following table 1 shows the exact functions of the research experts. In addition, the table contains information on the experts from the public transport companies and the disaster management authorities concerning the population living in the respective county or independent city. A legend can be found at the end of the table.

In order to find experts who would take part in the interview, the Association of German Transport Companies (VDV) was contacted to find potential interested experts from public transport companies and to draw their attention to the Master's thesis. The association then independently shared my expose in a newsletter via e-mail at short notice. The expose contained a doodle link through which the experts could book an appointment independently. It is possible that the expose was also shared beyond this. The VDV's independent initiative shows that the association supports the topic and has made it very easy to find experts. Nevertheless, how exactly the experts became aware of the thesis is not entirely comprehensible. Most of the experts from the transport companies have the function of operations manager or are responsible for the bus sector. This means that, on the one hand, the experts have technical background knowledge and are well acquainted with the timetables and processes. However, on the other hand, they also work closely with the bus drivers because, for example, they coordinate training and are the contact points for potential problems. When it became clear that it was predominantly transport companies from large cities that would register, the disaster management authorities of the 30 largest cities in Germany were contacted to represent the perspective of the disaster management authority of a large city as well. In addition, some districts and administrative regions were also contacted to capture the rural character.

The research experts came to the author's attention through their current research projects and were contacted directly. This thesis presents all experts and the corresponding counties

and cities anonymously. The results are presented anonymously so that the experts feel free to discuss the topic and express criticism. In addition, the feasibility study should be generalizable to all cities and counties. Mentioning specific places could influence the reader of the thesis. All experts signed a consent form for the interview, describing how the experts' data were recorded, transcribed, anonymized, and analyzed. The interviews took place online via Zoom in February 2023.

Table 1: Participants of expert-interviews

Interview	Partici-pants	Type of Organization/Role	Population	Length of Interview
PT1A	2	Public transport operator	Urban: large city	46 min
PT1B	1	Public transport operator	Urban: large city	53 min
PT2	2	Public transport operator	Urban: large city	55 min
PT3	1	Public transport operator	Urban: large city	55 min
PT4	1	Public transport operator	Urban: medium city	45 min
PT5	1	Public transport operator	Urban: medium city	49 min
DM1	2	Disaster management authority	Urban: medium city	48 min
DM2	1	Disaster management authority	Urban: medium city	65 min
DM3	1	Disaster management authority	Rural/Urban	40 min
DM4	2	Disaster management authority	Rural/Urban	50 min
DM5	1	Disaster management authority	Rural	45 min
RE1	1	Research expert and practitioner of security and crisis management of critical infrastructures		42 min
RE2	1	Research and development expert in technical blackout solutions		48 min
RE3	1	Research expert about city development and crisis communication		66 min

1. **Urban: Large City: > 500.000 inhabitants**
2. **Urban: Medium City: 150.000-500.000 inhabitants**
3. **Rural/Urban: Either a county close to a large city with a suburban character or administrative regions with rural counties and urban cities**
4. **Rural: County with small cities (< 50.000 inhabitants)**

The interviews were conducted using the problem-centered interviews (PCI) approach. PCIs are usually an iterative process that combines inductive and deductive reasoning (Döringer, 2021). By combining these two approaches, PCI enables the use of both the researcher's previously accumulated theoretical and empirical knowledge and the respondent's individual knowledge and personal experiences (ibid.). Typically for qualitative research, much emphasis is placed on openness and flexibility (ibid.). All interviews consisted of three

question blocks, which differed slightly depending on the expert (PT/DM/RE). The exact interview guidelines can be found in appendix A-F. The first block of questions dealt with the current cooperation between disaster management and transport companies and the experiences already made. A very open question was asked in the second block to discover the experts' ideas for possible cooperation. In the third and central question block, the project idea was briefly presented, and the experts were asked to elaborate on their knowledge, experience, and concerns about the topic. The project idea is presented in chapter 4.1 as the starting point for the feasibility study. Generally, the findings from each question block can be used for any research. However, the main purpose of the first block was to collect information for the baseline and preparatory analysis. The second block was to test the author's assumptions and make the research open to new ideas. Finally, block 3 collected the information for the main investigation.

The beginning of each question block, as usual for PCIs, was narrative so that the interviewee could describe their knowledge about the topic/problem, but also their individual personal experience (ibid.). The experts already had time to think about the topic before the interview because they got the interview guideline a few days in advance. Only the project idea was not sent out beforehand, so the experts' ideas were not influenced. After the first part of each question block, which consists mainly of semi-structured and open-ended questions, the second part follows with specific follow-up or ad hoc questions (ibid.). The second, more structured part should eliminate possible misunderstandings, clarify the interviewee's opinion, and address topics that did not find a place in the dialogue in the first part.

3.3 Method of Analysis

The data analysis of the interview transcripts aims to systematically answer the research questions (Döring & Bortz, 2015). Since the data is non-numerical, qualitative data analysis was chosen. The qualitative analysis was done in two steps with the help of the software Nvivo. First, each interview was analyzed separately (within-case analysis) and then across cases (cross-case analysis) (ibid.). All interview scripts were first worked through sequentially, i.e., from front to back, and then the text was segmented into meaningful units and coded. This process was repeated iteratively. A code describes a summarizing or explanatory feature (ibid.). The codes were then grouped into superordinate categories/themes. Some codes/themes were obtained inductively from the data, like "new

ideas by the experts", "tasks of the transport companies" or the "current blackout plan" and "responsibilities". Next, many codes/themes were deducted from the Weiß (2003) feasibility study, like the broad categories of technology, organization, finance, legal and safety, and willingness to participate. If necessary, subcategories were introduced. For example, the technical feasibility was divided into the topics "electrification", "communication technology", and "fuel supply". Further subcategories can be found, according to the assessment of the results, in chapter 4. Since the broad categories were already part of the interview guide, an assignment was usually possible without any problems. In the cross-case evaluation, all codes and superordinate themes were considered, further summarized, and logically ordered (Döring & Bortz, 2015). These themes were then summarized and interpreted and presented in the following chapter according to the steps of the feasibility studies.

3.4 Limitations of the Methods

The chosen method of expert interviews has numerous advantages and strengths but also limitations. One limitation is that although the experts were contacted randomly, it can be assumed that only experts interested in the topic registered for the interview. This in turn suggests that these experts have already dealt with the topic of blackouts and that the corresponding company/authority has probably already considered the matter. The experts' positions in the company can also influence the results. Some experts in transport companies have closer contact with the bus drivers than others who only have contact with the organizational or technical aspects. The company's size or the experts' experience can also play a part in how good the experts' overview is. Even though many experts were quite critical, it is possible that some perspectives were not illuminated because the selection of experts was relatively homogeneous. Following this, the experts' statements can only be verified in a few cases. It is conceivable that the experts pretend to know the answer, especially in detailed questions, to avoid being perceived as not being knowledgeable. Furthermore, it is possible that the experts make statements that they are convinced are true but do not correspond to reality. Critical questions were asked or more arguments were demanded whenever possible during the conversation. Nevertheless, it cannot be ruled out that false claims were not identified.

Another limitation is the partial lack of detail to protect the experts' identity and keep the results general. Each county and city have specific local characteristics and a slightly

individual disaster management structure. For clarity, some statements have been generalized so that the challenges identified in the following chapter may have a greater/smaller impact in different cities/counties.

Furthermore, the interviews and the coding were conducted in German and only translated into English during the final analysis. Thus, the interpretation of the analysis itself and the choice of the most appropriate translation depends on the researcher. Particular meanings may have gotten lost in the translation. If there were several suitable words, the word most relatable for a German-speaking reader was always chosen, as the work results are intended to help German transport companies and disaster management authorities decide whether to cooperate.

4. Conducting the Feasibility Study

The feasibility analysis according to Weiß (2003) is carried out in this chapter. As a starting point for the feasibility study, the project idea is presented and explained how it is derived. In the first step, the basis and preparatory investigations are conducted. The basis investigation is relatively short because the project idea is generalizable and not for a specific application. This step describes the challenges, and the current blackout plans of the authorities and public transport companies. In the preparatory investigation, the actual state of the cooperation is described. The market situation and reference projects are also considered. After that, the main investigation follows in which the project idea is examined concerning technical standards, organizational demands, legal and safety frame, economic viability, and public and organizational acceptance. Subsequently, the different suggested functions of the buses are examined, and the ideas of the experts are evaluated.

4.1 The Project Idea

As Weiß (2003) recommended, the project idea was initially described in a very broad and flexible way. The ideas mentioned are the author's ideas, which emerged from literature research and the author's own voluntary and professional experience in disaster management and blackout preparedness. It is important to acknowledge that inspiration for new design ideas can come from different sources and be of creative nature (Hevner, 2007). According to Hevner (2007, p. 4), pure theory-grounded design research is “unrealistic and even harmful” for the project, because it may limit the creativity and innovation of researchers.

This project idea was presented to the expert during the interview in question block 3:

- *For the first 0-8 hours, the buses run their usual routes, broken-down trams are towed from the streets, people are evacuated from trams and lifts.*
- *After that, the buses are provided with information/work orders by the emergency services every 1-2 hours.*
- *The buses then follow established bus routes (e.g. night bus routes).*
- *The bus radio network's base station(s) were equipped with emergency power in advance so that the buses can communicate with a control center/crisis team at any time.*
- *The population was informed about the buses' special "crisis function" by advertising on buses and in the media.*

- *Staffing plans and liaison persons for the emergency response team were defined in advance; spontaneous helpers provide support.*

Possible functions of buses/bus drivers:

- *Distribute information via notices at the bus stops*
- *Forward requests for help from the population*
- *Report accidents, fires, riots, or similar - Complete situation picture*
- *Transport employees of critical infrastructure*
- *Transport relevant goods (e.g. medicines)*
- *Depending on the season, buses can serve as heat islands or transport people to heat islands*

4.2 Basis Investigation

This chapter explains the specific challenges transport companies and disaster management authorities face during a blackout. This step is necessary to see how cooperation can help both parties to get better control of the situation. In addition, the various frame conditions are shown, which could enable or prevent a concept for cooperation from the outset. Already existing cooperation is examined in the preparatory investigation.

The disaster management authorities have identified various key areas. It is essential to keep the critical infrastructure running and supplied with fuel, including hospitals, the fire brigade, and the drinking water supply (DM1, DM2, DM3, DM4, DM5). Another priority is to provide the population with information and to be able to answer emergency calls from the population. For this purpose, the Disaster Protection Lighthouses are partly set up (DM1, DM2, DM5).

Communication with the population (DM1, DM2), alerting of own personnel (DM1, DM2, DM5), and fuel logistics (DM1, DM2, DM4, DM3, DM3, DM4) are mentioned several times as a particular challenge of the disaster management authorities.

The transport companies have different priorities in the event of a blackout. The highest priority is to evacuate passengers from the underground or tunnels (PT1A, PT1B, PT2, PT3). After that, the tunnels are secured. Of course, this only applies to transport companies with tunnels and rail vehicles in their city. The transport companies PT2, PT3, and PT5 would decide whether to maintain their operations depending on the disaster management authority and the available personnel if a blackout occurs. PT4 will support the city in providing mobile Disaster Protection Lighthouses and certain transport services through the

buses during a blackout. Experts from transport company PT1A and PT1B give contradictory information about their plans during a blackout. All transport companies have fuel reserves and a partial emergency power supply.

Overall, the biggest challenges of the transport companies are the communication with the employees on duty and the employees at home who do not know if/when they are supposed to come to work (PT1B, PT2, PT3, PT4). Consequently, the variable personnel cannot be planned, and information is needed from the disaster management to make decisions.

The identified deficiencies and challenges of the disaster management authorities and the transport companies provide information on which components should not be missing in the developed concept. Furthermore, the basis investigation aims to identify which frame conditions could make the concept applicable or lead to a rejection of the idea. This includes factors such as: should the project take place in a rural or urban area, is the project in a county or district-free city, does the transport company use electricity-dependent means of transport such as the underground, trams, or electric buses, or is there perhaps already another successful form of cooperation? Since this thesis looks at the project idea holistically and not only at a context-specific application, all frame conditions are considered first. More detailed advantages and disadvantages of certain frame conditions can be found in the main investigation.

4.3 Preparatory Investigation

This chapter analyses the market situation, referential projects, and the current practice regarding cooperation. A market analysis is a systematic investigation of the market to gain information and insights into market conditions, market development, the competitive situation, customer demand and other relevant aspects (Herrmann & Huber, 2009). As already described in the introduction, there are currently no research projects in Germany that deal specifically with the cooperation between transport companies and disaster management authorities. Consequently, no published reference projects are known at present, so there is no market which could be analyzed. Nevertheless, there is great interest in the blackout scenario, which is not only reflected in the media coverage but also in the interest of the experts. All the experts have a positive attitude toward the fact that they have to prepare for the scenario and are interested in the research results. One expert said:

"good topic, good that you are dealing with it. We would like to base our further action on your research" (PT1B). The participants' response, measured by the number of interviews who registered themselves, also confirms that the topic is highly relevant and timely. At this point, however, it should be remembered that only experts who are themselves convinced that good blackout preparedness is important took part in the survey. A detailed market analysis cannot be carried out within the scope of the work, as not enough information is available, nor is any specific context considered. However, the high interest in the work and the low number of reference projects indicate a good market situation, as there is an apparent need for a solution but no competing proposed solutions.

Even though there are limited publications of previous cooperations, numerous examples are mentioned in the interviews. Two disaster management authorities already have concrete agreements with the transport company on the blackout scenario (DM1, DM2). The other disaster management authorities have an emergency plan for the blackout scenario, but the transport companies are not part of it yet (DM3, DM4, DM5). In one city, shuttle buses would be set up to transport critical infrastructure providers during a power blackout (DM1, DM2). Many transport companies would make their fuel reserves and company petrol stations available for disaster management (DM1, DM2, PT1A, PT1B, PT4, PT5).

Nevertheless, some authorities have already gained experience in cooperation. For example, some transport companies already support disaster management when there are evacuations, e.g., due to bomb disposal (DM1, DM4, PT3). During the refugee crises or the Corona pandemic, some transport companies have also provided additional support (PT1B, PT2, PT3, PT5). Some experts have also gained cooperation experience through joint staff work (PT1B, PT2, PT3, PT4).

4.4 Main Investigation

In this chapter, the five assessment criteria according to Weiß (2003) are examined with the help of the interviews. Subcategories are formed where necessary. The underlined paragraphs represent a small summary of each topic.

4.4.1 Technology

The area of technical feasibility is very large and includes many sub-areas such as the technical implementation of communication, the maintenance and operation of the buses, as well as the refueling of the buses and the operation of the refueling station. Some

transport companies do not see any challenges in technology currently, as it can be well coordinated, and it is known which resources are available in the blackout (PT3, PT4). PT4 mentions that "in the area of technology, everything is basically settled. Communication is given, refueling works, and the vehicles are ready for use". Another transport company, on the other hand, says: "In our case, the bus radio is dependent on mobile radio, which would fail after about 30 minutes. Then no more buses would run because communication is a basic requirement" (PT2).

Technical Implementation of Communication

In the area of communication, three essential areas came up in the interviews: Communication within the transport company internally and between the buses, communication with the disaster management staff, and communication with the employees to communicate work schedules and availabilities. The latter is considered an organizational aspect and analyzed in chapter 4.3.2. Communication with the disaster management staff was neglected, as this is a relatively small interface that can be realized at short notice and without many resources using the bus radio, satellite telephones, or a handheld radio of the disaster control staff.

In the area of internal communication, communication works perfectly at one transport company (PT4) and at two with restrictions (PT1A, PT5). At two, it does not work; one company would continue to drive and communicate through verbal agreements (PT3) and the other would stop bus operation (PT2). The disaster management authorities made similar statements. At one local transport company, communication would be down, but the buses would still run (DM1), at one the bus radio is on emergency power (DM2). The other disaster management authorities could not give any information because they are unaware of it or because different transport companies operate with different equipment. The experts for whom communication does not work in a blackout see the high costs of implementing another communication system as the main obstacle. Each bus would have to be equipped with new technology, some of which is incompatible with other systems such as the operations control system or GPS forwarding. Thus, this investment would not benefit their daily business (DM1). In counties, another problem is that there are several transport companies, which would then all have to be equipped, and in addition, more repeater stations would be needed because the area is so large (DM5).

All in all, the area of communication can be implemented feasibly by transport companies that either already have an emergency-powered communication system or that operate in a medium-sized city, as here it is still possible to work with agreements. At the same time, in large cities, the routes are too complicated even for experienced bus drivers without a functioning bus guidance system. In rural areas, it is very difficult to implement communication due to many actors and the size of the area served.

Maintenance and Operation of Buses

There are currently no significant challenges in the maintenance and use of the buses. Diesel buses can run without any problems, and all required operating materials are usually in stock (PT1A). Some transport companies have even equipped a workshop with emergency power to carry out simple maintenance tasks during the blackout (PT3, PT4). Another transport company emphasizes that it is also important to save resources, as no maintenance can be carried out, and thus minor defects lead to the failure of the bus (PT1B). From the company's point of view, it is better to use a few buses during the blackout to be able to resume operations as quickly as possible after the blackout (PT1B). That would result in low frequency or less operated lines.

With only one exception, all experts agree that increasing electric mobility will become a challenge in the coming years when using buses in the event of a blackout. Only expert DM3 did not consider this issue yet. The starting point for this is the EU's "Clean Vehicle Directive" (European Union, 2019), as well as the political interest of many cities to become emission-free in the coming years (PT2, PT3, PT4). The Clean Vehicle Directive serves to efficiently reduce carbon dioxide (CO_2) emissions in the transport sector and thus to comply with the Paris Agreement (ibid.). Member States are obliged to transpose it into national law. No exemptions are foreseen for buses used for passenger transport, as is the case for fire and rescue service vehicles (ibid.). The target is that by the end of 2030, at least 65% of buses acquired through public procurement must be powered by a clean engine (BMDV, 2022). A heavy-duty vehicle, such as a bus, is clean if it emits less than 1 g CO_2/kWh or less than 1 g CO_2/km (European Union, 2019). Clean propulsion methods for buses are e.g. plug-in hybrid buses or buses that run on electricity, hydrogen, natural gas, or biofuel (BMDV, 2022).

The increasing use of electric buses creates many challenges, as they cannot be charged in case of a blackout and, therefore, cannot be used. Since all rail vehicles and trolley buses

already fail in the event of a blackout, the last means of transport would also be interrupted (RE1). Charging via emergency generators would be technically and economically inefficient (PT2, PT3, PT5). Furthermore, electric buses need hours to be charged, while diesel buses can be refueled within minutes (PT2, PT4, DM5). Batteries' limited availability and technical progress are also seen as problematic (PT1B, PT2). According to the clean vehicle directive, it would still be possible to maintain diesel buses after 2030, but there must also be a political will to do so. For this to happen, however, politicians must first recognize that transport companies, as critical infrastructure and due to their important resources, should be as resilient as possible (PT2, DM1, DM2). In addition, more and more bus manufacturers are switching entirely to electric buses so that diesel vehicles will no longer be procured in the future (PT2, PT3).

Possible alternatives are also discussed during the interviews, such as trolleybuses, which, however, also fail after a short time in the event of a blackout (PT1B). Also, hydrogen or natural gas was discussed (DM4, PT2), but it cannot be stored in large quantities in the city due to a possible risk of explosion (RE1). Another alternative is synthetic fuels/e-fuels (PT1B, PT4) which have a rather low efficiency but can be stored well, according to the international council on clean transportation (Searle, 2020).

Currently, there are still enough diesel buses available in the cities and counties of all experts interviewed. With increasing vehicle fleet electrification by 2030, it must be considered whether there is a political will to keep diesel buses for emergencies such as a blackout, to operate some lines on low frequency. Other zero-emission or low-emission propulsion methods may also develop further in the coming years and represent sustainable but still crisis-proof alternatives.

Fuel Logistic

All fuel supplies are very valuable in the event of a blackout because not only can (emergency) vehicles be refueled with them, but also emergency power generators that supply, for example, hospitals, water utilities, or administrative buildings with emergency power (Mayer, 2017). Private petrol stations where citizens refuel rarely have an emergency power supply to operate the pumps. Another problem is the cash register system, which must also have an emergency power supply and be connected to the internet. In this way, the petrol stations ensure that everything is correctly accounted for and is being taxed

(ibid.), DM4). This hurdle does not exist with operational filling stations. Transport companies usually stock fuel for at least 6-7 days at full load to be prepared for possible supply shortages or inconveniently timed public holidays (PT1A). Thus, several hundred thousand liters of diesel are usually stored at a transport company (PT1A). In some cities, there are already arrangements for emergency services to refuel at transport companies in a blackout scenario (PT1A, PT1B, PT4, PT5). The interviewed transport companies have enough diesel in stock to refuel their own buses as well as to be able to deliver fuel to the disaster management. In other cities, no arrangements have yet been made for the use of supplies because either it is not known whether such supplies exist (DM5) or other fuel reserves would be used primarily by disaster management (DM4, PT2, PT3). All transport companies can access their stocks through an emergency power supply or a hand pump during a blackout.

Refueling diesel buses is not a challenge for the interviewed transport companies. The diesel stocks can even serve as a resource for the disaster management authority. However, it should be considered that an increase in electric buses also means that less fuel is kept in stock in the long run because it is simply no longer needed in regular business (PT4, PT5, DM2, RE1).

4.4.2 Organization

In the organizational dimension, one challenge is to first recognize a blackout as such (DM4, PT1B, PT4, RE2). A large power outage is easy to identify if the communication between the buses or the mobile phone system is still working. It is possible to find out relatively quickly whether the blackout affects the whole city or is even transregional. However, how does one determine how long the power outage will last and when normal operations will be halted, and a crisis mode will be started? A disaster management authority has arranged with the local power grid distributor to get this information as quickly as possible (DM4). One transport company note: "We would only switch to such a crisis mode when it is clear that we have a crisis lasting several days, as it is quite an effort to start such a mode" (PT1B).

Personnel Planning

Another major challenge mentioned by all experts is the personnel. Many operators do not know how to alert their staff or communicate work schedules to their employees (PT1B, PT2, PT3, PT5, RE1). Even if this challenge can be overcome by making arrangements in advance,

nobody knows who will still come to work in such a scenario. After all, each employee is affected and may prefer, according to the interviewees, to look after their family, guard their property, or cannot get to work because the traffic is not working as usual (DM1, DM5, PT1B, PT3, PT4, PT5). It is important to mention that not only bus drivers are relevant, but also, for example, technicians and control center staff (PT1B, PT3). In some transport companies, employee availability was also surveyed as part of the Corona pandemic or emergency plans for the blackout scenario (DM1). However, such queries can only be based on voluntary participation due to data protection (DM4). It is expected, however, that at least those employees who have no other obligation will come to work and are happy to help in this situation (DM3, RE3).

For the feasibility of the concept, it is important that the blackout can be identified as one as quickly as possible. Furthermore, one of the most critical variables is that personnel is available. Estimating how many employees will come to work during a blackout is difficult. To address this uncertainty, arrangements can be made with the employees, and it should be communicated internally what the task of the transport company is during a blackout so that the employees know that they are needed.

Timetable and Traffic

When setting up a crisis bus operation mode, most experts agree that one should use already established routes already known to the population. For example, in a city where a radial network of night buses connects all districts, these routes could be used at any frequency (DM1, PT3, PT4, PT5). Holiday timetables could also be used, as the regular routes are served but much less frequented (PT1A, RE2). In rural areas, buses sometimes only run twice a day (DM5). For example, it could be communicated that the first route is always served after sunrise. However, if the bus only comes once a day, the question is how useful this route is since it is not a real alternative for people who have to go to work, and the other proposed functions are only implemented to a limited extent (DM5, RE3).

Another option would be to use printed bus routes to run specific routes that the disaster management authorities consider necessary because they connect important places (PT2, PT5, RE1). In large cities, there is the additional challenge that, especially in the city center, traffic is usually provided by trams, metros, or trains (PT3). Buses usually only take over a

roadwork site operation and serve as a shuttle to essential stations. Consequently, the whole city center will stand still if the power fails as no regular service is provided by buses (PT3).

Another critical point, especially in large cities, is staff change. In regular operation, the staff is changed on the route, but this only works if they can get from one point to the other by themselves (DM1). Furthermore, some cities are also located in metropolitan areas, so arrangements must be made with neighboring cities to be able to establish continuous transport so that employees can also get to work beyond the city borders (PT5).

Another unpredictable variable is traffic and possible traffic chaos, depending on the time of day (DM2, DM4). Especially in the city centers, a large traffic volume can be expected during the day. Traffic jams will occur due to the failure of traffic lights and accidents (DM2, PT2, PT3, PT5, RE2). In addition, especially in the first hours of the blackout, many people will be on the road to run errands, pick up children from school, or drive home themselves (DM2, DM4). After a few hours, more calm is expected because people are mostly at home and the car fuel is running low (DM2). A tense and chaotic traffic situation is also expected by the literature (Petermann et al., 2011).

In conclusion, implementing crisis timetables is associated with some context-specific challenges. Here, a system analysis must always be carried out individually in advance to record the individual situation in a city/county and implement a crisis timetable accordingly. Whereas in large cities, rail transport needs to be replaced, defining new, required routes makes sense. In medium-sized cities, established bus routes with a lower frequency are suitable. In rural areas, transport connections are often difficult even in regular service, so it makes more sense to implement acutely needed transport services here instead of setting up a regular service. The paradox is the resulting traffic chaos. If a blackout occurs during the day, all people will want to go somewhere in the first hours and will be most dependent on buses. At the same time, however, they can only run to a limited extent because there will be numerous traffic jams.

4.4.3 Finance

All five disaster management authorities have expressed their views on the issue of financing. There is consensus that two scenarios must be distinguished whether the "state of emergency" has been declared. If the disaster has been declared, the authorities can call on needed resources, which the transport company later invoices and is reimbursed for the

costs incurred (DM1, DM3, DM4). The situation is ambivalent when it comes to purchases prior to the potential blackout. If the respective transport company is a city subsidiary, the city can decide and finance investments (DM1, DM2). In rural counties, however, there are usually several private transport companies. Here, any investment is much more complicated because it would usually have to be carried out several times for each transport company (DM5), and not only the counties but also the municipalities and operators are jointly responsible (DM3, DM4). In addition, it is unclear whether the resources are available during a blackout because these transport companies are often not only responsible for one area/county, and the depots are sometimes far away (DM5). The statements of the transport companies generally agree with this (PT1A, PT1B). Some transport companies see the responsibility and decision on investments for the blackout case with the city, mainly if the transport companies are financed by the city (PT1B, PT2, PT5). However, some also see themselves as responsible and have already made many investments (PT4).

Furthermore, during the interview with RE3, the comment came up that it makes sense not to create new infrastructures but to give already existing structures/functions a crisis function. For example, advertising media which can be used for crisis communication were mentioned. The same principle also applies to the use of the resources of the transport companies, as these already have an established function in everyday operations.

Overall, financing becomes feasible when the transport company is owned and financed by the city or takes its operator's responsibility so seriously that it pays for investments on its own. Thus, financing becomes a hurdle in rural areas where often several transport companies operate or when the city does not see the need for investment. The latter is discussed in more detail in the "Willingness to Participate & Acceptance" chapter.

4.4.4 Legal & Safety

This thematic section discusses the legal framework in which the presented concept would be possible. One discussed aspect is the safety of bus drivers and potential passengers and protection against acts of crime. Furthermore, many experts consider the property protection of bus depots necessary. Finally, this chapter examines the authority to issue directives and the legal basis for possible cooperation.

Some experts believe that bus drivers are the most capable of assessing safety themselves and driving back to the bus depot if they feel unsafe (DM1, DM4, PT2, RE2). The experts also

assume that neither the drivers nor the bus would be potential targets of attack because the population would be grateful for the help (DM1, DM2, DM4, PT3), and a bus or the diesel could also only be stolen with expert knowledge (RE1, RE2). Other experts see it as necessary to have security personnel, e.g., from the police or the Federal Armed Forces, on board so that the bus can operate at all. However, the experts also note that this security personnel would probably not be sufficiently available in a blackout (DM5, PT1B, PT4, PT5). Furthermore, the transport companies note that in particular the bus depots with petrol stations, the emergency power supply, and the fuel reserves must be protected by the police (PT1A, PT1B, PT2, PT4, PT5).

In the course of the research project on disaster protection lighthouses, the social behavior of the population in a crisis was also researched, and predominantly prosocial or even altruistic behavior is expected (Ohder et al., 2015). A literature review by Rubin and Rogers (2019) also concludes that more altruism is expected during a blackout. In past disasters, looting and crime have been identified in some scenarios, such as the New York Blackout or Hurricane Katrina (Mahdavian et al., 2020). However, despite widespread worries of looting, there was a little bit more criminal activity than usual during the Kista blackout in a suburb of Stockholm, Sweden (ibid.). Although there have been crimes committed during blackouts in the past, this does not mean that it will always be the case. Crime during a blackout may occur depending on a number of variables, including the length and intensity of the blackout, the authorities' level of readiness and response, and community members' actions (ibid.). In addition, other elements including social standards, economic situations, and cultural values might also have an impact on the amount of crime that occurs during a blackout (ibid.). Official interventions such as providing information to the population and carrying out pre-prepared blackout measures can promote altruistic behavior (Rubin & Rogers, 2019). Even if science cannot completely rule out egoistic behavior, the population is expected to behave altruistically. Measures to reduce the impact of a blackout, such as the proposed concept, can have a positive effect on the behavior of the population and reduce crime (Mahdavian et al., 2020; Rubin & Rogers, 2019).

In traffic safety, the experts do not expect any significant challenges (DM1, DM3). Accidents are most likely to occur immediately after the traffic lights fail (DM4). Afterward, traffic jams are more likely to occur (DM4). In some cases, the failure of street lighting is also seen as problematic (DM3, PT1B). One expert also notes that drivers' periods of rest, which are

regulated by law, should be considered. Even if these can be extended in a crisis, traffic safety should not suffer (PT1B).

As mentioned in chapter 2.2, there is also a legal basis for the use of the resources of transport companies by disaster management authorities. As soon as a disaster situation is declared, the resources of the transport companies can be requisitioned at any time. Depending on the disaster protection act of the respective state, there are deviations in the exact wording and the scope of powers. The experts also see the disaster management authority as empowered to issue directives during the disaster (DM2, DM3, DM5, PT2, PT3, PT4). The same experts see the disaster management authority as entitled and responsible for making decisions on the exact course of action. The transport companies do not have the necessary information and overview to decide how to support during a blackout and need clear instructions (P2, P3, P4). Before the disaster, purchases, or exercises, for example, can only be made by agreement and mutual consent (DM3, DM4, DM5, PT1A, PT2). If the transport company is a city subsidiary, it is much easier for the city's disaster management authority to enforce and finance its interests (DM2, PT2). The disaster management authorities from one rural county also pointed out that each municipality must make arrangements with the transport companies and that the county is not responsible for this (DM3).

In summary, from a legal perspective, nothing is to be said against cooperation between disaster management authorities and transport companies. While traffic safety is probably not a significant problem, the population's behavior concerning increasing criminality should be monitored, because the behavior cannot be accurately estimated. However, not using the cooperation concept, because of concerns about crime is not justified, as good blackout measures can further strengthen the already altruistic behavior. The respective disaster control laws of the states regulate the confiscation of resources during a crisis. For successful cooperation, however, arrangements should be made in advance mutually.

4.4.5 Willingness to Participate & Acceptance

This chapter is divided into three aspects. The willingness to participate of the transport companies towards the proposed concept, that of the disaster management authorities to cooperate with the transport companies, and the population's acceptance of such a concept. At this point, it should be mentioned again that all experts interviewed presumably have a

relatively positive underlying attitude towards the concept and have already dealt with the blackout scenario, as they volunteered to be interviewed. Other transport companies or disaster management authorities that did not agree to be interviewed may have a more negative attitude towards the concept.

So far, the disaster management authorities have had good experiences cooperating with the respective transport companies. They describe them as "excellent collaboration" (DM1), "very cooperative" (DM2), "always open for discussions" (DM3), and "willing to talk and accountable" (DM4). Only expert DM5 does not expect much from agreements, which was justified by the fact that the bus companies operate in several districts due to the rural location and thus would also have to make agreements with several districts, and the responsibilities are unclear.

Among the transport companies, only one expert has a negative attitude towards the concept presented. The expert criticizes: "this is not my business. For the distribution of information, there are warning apps or sirens. I do what I can, and I am not willing to do anything else. Who would pay me to do that?" (PT1A). All other experts from the transport companies have a high level of acceptance in supporting disaster management, provided that the problems discussed can be solved.

Regarding the transport companies' willingness to participate, the bus drivers' individual attitude and qualification also has a significant impact. If they must take on new tasks, such as forwarding requests for help or distributing information, this can lead to overwhelming stress if the bus drivers have not been trained for this or if there are language barriers (PT1B, PT3, RE2). This can mean that the bus driver can no longer concentrate on their task of driving the bus. However, some experts also rate the helpfulness of bus drivers very high (DM3, PT5, RE1). To solve this problem, the bus drivers could be trained for such a scenario, or the task of the bus driver could still be limited to driving the bus; instead, someone would drive along to coordinate all the other tasks. These people could be either employees of the transport company or the administration who are not needed in their regular function or spontaneous helpers from the population (PT3, RE2).

The population is expected to perceive any help and sign of normality, such as operating buses, as positive during the crisis (DM1, DM2, PT1A, PT2, PT4, PT5, RE2, RE3). Only the risk communication, including the crisis function of the buses, raises different views. Some

experts are very cautious in communicating with the population because they fear that the information will incite panic or be misused by political groups to polarize (DM1, DM3, DM5). Other experts, in contrast, expect great support from the population and find it essential that the crisis function of the buses is also communicated in advance (DM2, PT1B, PT5). The literature often speaks of the "panic myth", as there is no evidence that informing the population about the danger of a blackout triggers panic (Saurugg, 2016). It is rather assumed that timely information leads to better preparation of the population and consequently eases the situation (ibid.). Petermann et al. (2011) also see risk communication in advance as an important instrument for informing the public about the risk of blackout. Expert DM3 distinguishes between the urban and rural differences. While the bus is an integral part of the cityscape for the urban population and a crisis function would be perceived positively, the rural population would probably be more resentful if the buses ran more regularly during a blackout than on a normal day.

The willingness to participate and the acceptance of a concept of cooperation seems to be high among the transport companies and the disaster management authorities. The experts expect that the citizens would also perceive cooperation as positive. The experts disagree on whether the special functions of the buses should be communicated to the population before the crisis.

4.5 Examination of the Proposed Project Idea

This chapter is about the reflection on the proposed project idea (chapter 4.1). First, the experts' opinions on the presented functions of the buses will be considered. In addition, new ideas from the experts will be presented.

4.5.1 Criticism of the Presented Functions

Distribute Information

This function is predominantly received positively. Two experts noted that the bus driver needs the support of extra staff to accomplish the task (PT2, RE2). Moreover, it would be more effective to use regular cars to save fuel and be more flexible if the bus has no other function on this route (DM5, RE1). PT3 notes that in big cities, it is unrealistic to go to all stops, and DM4 says there could be confusion because the system with the disaster protection lighthouses has already been communicated. DM3 and PT1B could well imagine an implementation. Expert DM1 is very positive because the digital passenger information

system at bus stops is already used to warn the population of other disasters. So, the population already perceives the bus stop as a warning medium. Expert RE3 agrees with this and mentions the “digital passenger information system light,” which is battery-operated and thus also functions during a blackout. However, a radio connection would have to be established that would also function during a blackout. Standard passenger information systems can also be supplied with emergency power via solar panels and a battery, but high costs are expected here (RE3).

The expert interviews revealed that the bus driver is a personnel resource, and the bus stop is a central element. Experts DM3, RE2, and RE3 identify the bus stop as a possible place for neighborhood support. In addition to simple announcements from the official side, a bus stop can also be used as a bulletin board to coordinate neighborhood help. For this function to be known in the crisis, the bulletin board function could also be offered in everyday life, for example, to share local events. RE3 notes that especially solutions that involve a large investment, such as an emergency power supply, could be financed through advertising. Often, the advertising boards at bus stops and the passenger information systems are already used to warn the population; this medium could be further expanded and made blackout-proof.

Forward Requests of Help and Overview of the Situation

Several experts think forwarding requests for help and information about the situation is a good idea (DM2, DM3). PT1B and RE2 note that the bus drivers are not qualified for this task, and additional staff would have to travel with them. This staff could be volunteers from disaster control, spontaneous helpers, administrative staff, or employees of the transport companies who cannot perform their regular functions (DM3, PT3). PT2 and RE1 say this function only makes sense if communication with the staff of the disaster control authority is clarified, whereas DM1 also thinks the idea is still good if there is only written communication that is delayed.

Transport People or Goods on Request

This function includes all transport services such as the transport of schoolchildren, critical infrastructure staff, vulnerable groups of people, or the transport of goods such as medicines or suchlike. When transporting goods, DM1 and PT1B note that additional personnel may protect these from theft. Especially in rural areas, other more suitable vehicles may be

available for this purpose (DM5). RE1 also sees the securing of loads as problematic. PT1B, PT4, PT5, and RE3 see no problem in this area if the goods are not too heavy. Especially at the beginning of the blackout, it will be a big and important task to transport commuters and schoolchildren home (PT2, PT3, RE3, DM3, DM4). Vulnerable groups of people, such as people from elderly and nursing homes, can be brought to heated accommodation by the buses (RE3, PT1A, PT2, PT3, PT5.) It is crucial here that either the routes are planned in advance or that the disaster management authority requests individual transport services (RE1, RE2).

Operating as Heat Islands

The interviews show that this function only makes sense for particularly vulnerable groups of people (DM4, PT1A, PT2, PT5, RE2, RE3) or with a linked transport to a traditional warming shelter. Otherwise, it will be very resource-intensive to offer the function to relatively few people. It is also questionable how to motivate people to leave again if the bus is the only possibility to warm up (RE1, DM1, PT1B).

4.5.2 New Input from Interviews

During the expert interviews, some completely new ideas came up, which should not go unnoticed.

One idea is to use the buses as moving or stationary disaster protection lighthouses (DM2, DM3, RE3). Since disaster protection lighthouses are already established in many cities, the buses would be a good addition as further lighthouses if, for example, a lighthouse is out of order, or some villages/districts do not have a lighthouse. The buses have the advantage that they offer protection from rain and wind, have light, and even limited electricity. In some cases, there is even a communication system. Alternatively, the fire department's radios can be used, as they would be in charge of the lighthouse. In some cases, mobile disaster protection lighthouses are already planned, which will be realized by fire department vehicles. If the buses take over this function, the fire engines would be free for other tasks (DM3).

Another input from some experts is the experience that good cooperation is also essential before the crisis. This is the only way to get to know contact persons and to put agreements into practice (PT3, PT1A). Exercises also help to transfer theoretical concepts into practice (DM2). PT1A and PT1B note that plans will not work if only developed for the crisis. In PT1B's

city, there is a modular system where suitable modules such as evacuation can be accessed by disaster management. This means that the disaster management authority and the transport company are in regular contact and are used to working together even during minor incidents. Such a modular system can be applied to different disasters/scenarios, making it flexible and scalable.

Furthermore, ideas are mentioned that fall outside the scope of this master's thesis but could still be relevant to the reader. On the one hand, some experts note that certain functions can also be taken over by other companies, such as municipal utilities, waste management companies, or simply the service staff of transport companies instead of bus drivers. All these actors usually have many vehicles and staff with local knowledge (PT2, DM5, RE1). PT3 also notes that underground stations, for example, can be used in hot or cold weather, as they usually have a constant temperature. However, for use in a blackout scenario, at least lighting would have to be organized. RE3 also has the idea that battery-powered medical devices could be charged in buses. Nevertheless, this idea is more applicable to coaches, which often have standard household 230 Volt plugs.

4.6 Presentation of the Cooperation Concept

During the main investigation, but also when looking at the individual functions, it quickly became clear that every possible cooperation is always strongly dependent on the respective context of the city/county. Cooperation between transport companies and disaster management authorities is possible in any case and makes sense in many cases. However, not all functions are always useful or practical. The practicality depends, for example, on whether the context is rural or urban, whether the means of communication on the bus works in the event of a blackout, and so on. In addition, the effects of a blackout cannot be completely determined since, for example, the behavior of the population or the time of occurrence (time of day and season) cannot be planned.

For this reason, the functions that the transport companies could take over are classified according to the available resources (diesel, bus drivers, stops, buses) and can be implemented independently and scaled as desired (see table 2). Previously, the project idea always referred to functions such as "distribute information via notices at the bus stop" or "transport employees of critical infrastructure". Since these functions are dependent on many factors, the result of the feasibility study, the concept, concentrates on the resources

that are needed to implement the functions. For each resource there are different modules that are not mutually exclusive. As soon as all requirements from the following table have been fulfilled or procured/implemented, the corresponding module can be implemented ad-hoc as required during a blackout. The derivation for the modules and the requirements is taken from the feasibility study (chapter 4).

Module 1 covers the resource of fuel, which could be used by disaster management to supply vehicles or emergency generators of critical infrastructure or own needs. The personnel requirements on the part of the transport companies are low, as only the filling station and the gateway to the facility need to be staffed. The technical requirements are accessibility to the fuel via hand pumps or emergency-powered pumps. Furthermore, there must be a security concept to protect the asset. In principle, the module can be applied to any transport company, whether in a rural or urban context. In the rural area, it must be clarified whether only one or several counties want to use the fuel to divide the resources meaningfully.

The second module deals with the resource of the local bus driver, who can forward information about the current situation and requests for help to the disaster management staff. As a prerequisite, a variant of module 4 must also be active because, without the bus, the bus driver cannot perform these functions. Depending on which variant of module 4 is active, the personnel requirements also depend on this. In addition, for this module, a functioning communication possibility between the bus and the control center or disaster management staff is required, as well as additional personnel who can assist the bus driver in the tasks or take over the communication. This additional staff can be volunteers, spontaneous helpers, or employees of the transport companies or the administration who have no other task. This module seems to make sense only in urban areas, since implementing a resilient communication system in rural areas would be very costly. Furthermore, a bus usually travels through different counties/municipalities in rural areas, where a different authority would be responsible in each case.

The third module comprises the resource of stops. These can be bus stops but also significant stops for trams or regional train stations. The first variant of the module (3.1) involves the least effort. The bus or other available vehicles are used to display notices at the stops with current information. In addition, the stops can also be used as a bulletin board to coordinate neighborhood assistance and to post additional information, according to

module 3.2. In this case, this bulletin board must be established, maintained, and advertised before the crisis. Both modules require a medium level of staffing during the blackout as the information needs to be taken to the stops. Although neighborhood outreach through module 3.2 is intended to be self-regulating, it can still be monitored to provide situational awareness. If module 3.1 or 3.2 is linked with module 4, where the buses distribute information, additional personnel should also travel along to support the bus driver. Module 3.3 proposes that the bus stops be equipped with emergency power and a radio link to serve as a digital source of information. This real-time data transmission requires very few personnel but is associated with high costs and effort in advance. Since bus stops in rural areas usually do not have the necessary prerequisites for digitized use, module 3.3 is only suitable in urban areas.

Module 4 describes how the resource of the (diesel) bus can be used. Individual transport services can be provided at the request of the disaster management authority (whether of goods, employees of the critical infrastructure, vulnerable groups of people, or similar) (module 4.1). Furthermore, individual emergency lines can be used in case of fluent traffic (4.2). However, predefined emergency- timetables are necessary for this. Alternatively, the entire bus network can be operated with a low frequency (4.3), but this is only possible in the case of a continuous traffic relationship if the usual route network is not dependent on rail traffic.

The personnel requirement increases with the first three variations of this module. Of the three variants presented, only 4.1 is suitable for rural areas since the traffic relations in rural areas are not useful for emergency or regular timetables. Finally, the buses can create additional or mobile disaster protection lighthouses (Module 4.4). This can be implemented in addition to or independently of the other variants from module 4. However, the lighthouses require knowledgeable staff and must be put into operation by a bus driver. Therefore, the personnel requirements are medium. The module is suitable for both rural and urban areas.

All in all, the concept presented in the following table is a highly simplified overview that can be further specified and supplemented depending on the application. Before a module can be implemented, the general requirements of the table should also be considered so that implementation can take place successfully.

Table 2: A modular, simplified, and scalable concept for the cooperation of disaster management authorities and transport companies.

Resources	No.	Modules	Staff Requirements	Technical Requirements	Organisational Requirements	Recommended Context
Fuel (Diesel)	1	Securing fuel needs of critical infrastructure and disaster management	Low	Fuel accessible	Security	Urban/Rural
Bus Driver	2	Collect information on the situation and requests for help from the population and make it available to the disaster management staff	Low-High	Communication tool	Additional, qualified staff, use of module 4	Urban
Stops	3.1	Inform the public via postings at the (bus) stops	Medium	-	Additional, qualified staff if combined with mod. 4	Urban
	3.2	Establishment of bulletin boards where information can be shared and neighbourly help can be coordinated on its own	Medium	Set up of bulletin board	Additional, qualified staff if combined with mod. 4	Urban/Rural
	3.3	Digital information transfer and display of current information via digital passenger information or integrated advertising boards	Low	Emergency power supply and radio connection	-	Urban
Bus	4.1	Carrying out individual transport services as required by the disaster management authority	Low	-	-	Urban/Rural
	4.2	Operation of specific lines connecting important nodes (emergency timetable)	Medium	-	Predefined timetables	Urban
	4.3	Operation of the entire bus network at a low frequency	High	-	Continuous traffic flow (no/low rail traffic)	Urban
	4.4	Establishment of additional (mobile) disaster protection lighthouses	Medium	-	Additional, qualified staff	Urban/Rural

General requirements:

1. Joint arrangements and exercises in advance
2. Adequate number of diesel buses (Module 1, 2, 4)
3. Communication between disaster management and the control center of the transport companies is established
4. If applicable advertise the special crisis functions of the buses/stops

5. Conclusion

In this chapter, the research questions are answered. To do so, the results of the feasibility study are summarized, and the next steps to implement such a concept are presented.

5.1 Answering Research Question 1

Research Question 1: What challenges do transport companies and disaster management authorities face during a blackout, and how is the collaboration between the organizations hitherto?

The basis investigation identified the main challenges of the disaster management authorities and the transport companies during a blackout. The disaster management authorities expect difficulties in informing the population, alerting their staff, and having enough fuel available. The transport companies, on the other hand, have fuel, a close relationship with the population through their daily business, and an unpredictable number of available personnel. However, transport companies depend on information and instructions from disaster management; otherwise, they lack the information to decide how to proceed. These findings speak in favor of considering cooperation. Contextual factors should always be taken into account that could exclude cooperation, such as a very rural character, strong electrification of the transport company, or whether other measures are already in place that work better in the respective context. If these criteria do not apply, the preparatory investigation is considered next. In the preparatory analysis, it was found that there is a great interest in the topic, it is highly topical, and there are also already numerous examples of smaller cooperations among the experts interviewed.

5.2 Answering Research Question 2

Research Question 2: What challenges must be overcome to implement a cooperation concept in practice feasibly?

The five categories technical, organization, finance, legal and safety, and willingness to participate were reflected regarding possible challenges in the main investigation. The results show that communication can be implemented feasibly by transport companies that already have an emergency-powered communication system or operate in a medium-sized city. However, implementation in rural areas is challenging due to the many actors and the

size of the area served. Other technical aspects, such as fuel supplies and available buses, are currently not a problem. However, this could change by 2030 when the bus fleet becomes increasingly electrified. Personnel availability and communication are crucial for the success of the concept, and crisis timetables need to be tailored to the specific situation of each city or county. Financing becomes a hurdle if the traffic company is not a city subsidiary and is in a rural setting. The legal implementation is feasible. Nevertheless, public behavior should be monitored to ensure the bus drivers' safety. The experts agree that the willingness to participate and the acceptance of the concept are high among transport companies, disaster management authorities, and citizens. For successful cooperation, pre-arrangements are essential. Besides, the experts critiqued the proposed functions and suggested how the cooperation could look. The feasibility study provides valuable insights into successfully implementing a cooperation process between transport companies and disaster management authorities during a blackout.

5.3 Answering Research Question 3

Research Question 3: How could a possible concept look like implementing buses/transport companies in disaster management to support a city/county to cope with a blackout situation?

The exact concept of how a possible cooperation could look like was presented in chapter 4.6. The investigation reveals that cooperation between transport companies and disaster management authorities is feasible and makes sense in many cases, but the practicality depends on various factors such as the context (rural or urban), communication capabilities during a blackout, and unpredictability of blackout effects. Hence, the potential roles that transport companies could undertake in disaster management are categorized based on the resources at their disposal, such as diesel, bus drivers, stops, and buses. These roles can be autonomously implemented and adjusted as needed, as indicated in table 2. Once all the requirements listed in the table are met or put in place, the relevant module can be promptly implemented during a blackout situation. The development of these modules and their requirements is derived from the feasibility study (chapter 4).

5.4 Implementation of the Cooperation Concept

After conducting a feasibility study with a positive result, as was the case in this work, a project can be implemented. Various steps can be taken to ensure that an innovation such as the proposed cooperation concept is successfully implemented. It is important to note that the work did not consider a specific context and only looked at the general cooperation between transport companies and disaster management authorities. In Germany, the disaster management authorities are responsible for blackout preparedness. Consequently, they would also be responsible for introducing and implementing cooperation. Nevertheless, the steps proposed below should occur in close collaboration with the public transport companies because they can provide important information. The concept can only be successfully implemented if all parties involved are willing to participate. In the following steps, the city or county's context and specific characteristics must be considered.

1. Concept development and assessment: The concept of the project is further elaborated and assessed to ensure that it achieves the set objectives and meets the requirements (Brown & Katz, 2009). For this purpose, the proposed concept from chapter 4.6 can be used and further developed.
2. Resource acquisition: The necessary resources, such as budget, staff, and materials, must be identified and acquired to complete the project (Kerzner, 2013). This can be done by preparing a detailed resource plan.
3. Project planning and implementation: A detailed project plan is prepared that includes all the steps and milestones of the project (Turner, 2014). The plan must be reviewed and updated regularly to ensure the project stays on track (ibid.). Hopefully, a blackout will never occur, so the project will not be implemented as with other projects. Nevertheless, all preparations should be made to activate the modules of the concept when needed. Joint exercises can help to identify and resolve problems.
4. Evaluation: Finally, the results should be reviewed and evaluated once the cooperation concept has been introduced. This way, success factors can be identified and reused in future projects. Lessons learned can be passed on to other stakeholders to avoid repeating mistakes (Kerzner, 2013).

These steps provide the first indications of how the cooperation concept can be successfully implemented.

5.5 Prospects for Future Research

During the literature research and the expert interviews, many exciting topics were discussed that could not be conclusively clarified within the scope of this thesis. However, some topics are essential so further research efforts would be welcome here.

Increasing electromobility currently poses a critical challenge in the field of disaster management. The dependence of disaster management on fossil fuels does not fit with current developments in terms of climate change. However, there is currently no other reliable solution for the operation of vehicles and emergency generators in case of a blackout. In this area, it would be exciting to research how disaster management can become more sustainable but also what the consequences of the clean vehicle directive mean for blackout scenarios.

In addition, it may be of great importance to further explore how the results of this thesis can be transferred to disaster situations other than the blackout. Since the resources could also be helpful in other catastrophes, one could consider how the concept or individual modules could be applied, for example, in the case of a flood, or which modules could be added.

In addition, the many uncertain factors, such as the availability of personnel, the population's behavior, and the traffic chaos that might arise, should also be examined more closely to make disaster management more effective in the future. Much research is still needed in all these areas to prepare disaster management for the demands of a changing world with various geopolitical and climatic challenges.

References

Angermeier, G. (2009). Machbarkeitsstudie. Retrieved 2023-04-16, from https://www.projektmagazin.de/glossarterm/machbarkeitsstudie

Arndt, L. (2019). VER stellt Tankanlage zur Verfügung – Im Katastrophenfall bleibt die Feuerwehr mobil. Retrieved 2023-02-10, from https://nrw-mosaik.de/ver-stellt-tankanlage-zur-verfuegung-im-katastrophenfall-bleibt-die-feuerwehr-mobil/

Bause, K., Radimersky, A., Iwanicki, M., & Albers, A. (2014). Feasibility Studies in the Product Development Process. *Procedia CIRP*, *21*, 473-478. https://doi.org/https://doi.org/10.1016/j.procir.2014.03.128

BBK. (2021). Living Guideline (01-2021) • Klärung und Erweiterung des KRITIS-Vokabulars. In B. f. B. u. Katastrophenhilfe (Ed.).

BBK. (n.d.-a). Das BBK stellt sich vor. Retrieved 2023-02-26, from https://www.bbk.bund.de/DE/Das-BBK/Das-BBK-stellt-sich-vor/das-bbk-stellt-sich-vor_node.html

BBK. (n.d.-b). Zivilschutz versus Bevölkerungsschutz. https://www.bbk.bund.de/DE/Infothek/Presse/Pressedossiers/_documents/pressedossier-artikel_zivil-bevoelkerungsschutz.html?nn=19910

Bezirksamt Mitte. (2022). *Bombenentschärfung: Evakuierungsmaßnahmen am 26. September 2022* https://www.berlin.de/ba-mitte/aktuelles/pressemitteilungen/2022/pressemitteilung.1248189.php

Birkmann, J., Bach, C., Guhl, S., Witting, M., Welle, T., & Schmude, M. (2010). *State of the Art der Forschung zur Verwundbarkeit Kritischer Infrastrukturen am Beispiel Strom/Stromausfall*.

BMDV. (2022). Gesetz über die Beschaffung sauberer Straßenfahrzeuge. Retrieved 2023-03-10, from https://bmdv.bund.de/SharedDocs/DE/Artikel/G/clean-vehicles-directive.html

Brown, R. G., & Katz, B. (2009). Change by design: How design thinking transforms organizations and inspires innovation. *Harper Business.*

Coppola, D. P. (2011). Introduction to International Disaster Management (Second Edition). In D. P. Coppola (Ed.), (pp. 139-207). Butterworth-Heinemann. https://doi.org/https://doi.org/10.1016/B978-0-12-382174-4.00003-3

Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches (3rd ed.)*. SAGE Publications, Inc.

DB Regio. (n.d.). Nahverkehr in Deutschland. Retrieved 2023-06-02, from https://www.dbregio.de/wir/nahverkehr-deutschland#:~:text=In%20der%20Bundesrepublik%20obliegt%20der,Sie%20werden%20als%20Aufgabentr%C3%A4ger%20bezeichnet.

Diekmann, T. (2022). Was alles am Strom hängt. *SWR*. https://www.tagesschau.de/wirtschaft/technologie/blackout-deutschland-vorbereitung-stromausfall-101.html

Döring, N., & Bortz, J. (2015). *Forschungsmethoden und Evaluation in den Sozial- und Humanwissenschaften* (5 ed.). Springer Berlin, Heidelberg.

Döringer, S. (2021). 'The problem-centred expert interview'. Combining qualitative interviewing approaches for investigating implicit expert knowledge. *International Journal of Social Research Methodology*, *24*(3), 265-278. https://doi.org/10.1080/13645579.2020.1766777

European Union. (2019). *Directive (EU) 2019/1161 of the European Parliament and of the Council of 20 June 2019 amending Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles*.

Geier, W. (2021). Strukturen, Akteure und Zuständigkeiten des deutschen Bevölkerungsschutzes. Retrieved 2023-02-24, from https://www.bpb.de/shop/zeitschriften/apuz/bevoelkerungsschutz-2021/327989/strukturen-akteure-und-zustaendigkeiten-des-deutschen-bevoelkerungsschutzes/

Halser, C., & Paraschiv, F. (2022). Pathways to Overcoming Natural Gas Dependency on Russia - The German Case. *Energies*, *15*(14).

Henneaux, P., Labeau, P.-E., & Maun, J.-C. (2012). A level-1 probabilistic risk assessment to blackout hazard in transmission power systems. *Reliability Engineering & System Safety*, *102*, 41–52. https://doi.org/10.1016/j.ress.2012.02.007

Herrmann, A., & Huber, F. (2009). Märkte analysieren. In *Produktmanagement: Grundlagen — Methoden — Beispiele* (pp. 31-83). Gabler. https://doi.org/10.1007/978-3-8349-8042-7_3

Hevner, A. (2007). A Three Cycle View of Design Science Research. *Scandinavian Journal of Information Systems*, *19*.

Hiete, M., Merz, M., Trinks, C., Grambs, W., & Thiede, T. (2010). Krisenmanagement Stromausfall - Kurzfassung. https://www.lfs-bw.de/fileadmin/LFS-BW/themen/kats/gemeinde/dokumente/Krisenhandbuch_Stromausfall_Kurzfassung.pdf

IM BW. (n.d.). Warnung der Bevölkerung. Retrieved 2023-02-01, from https://im.baden-wuerttemberg.de/de/sicherheit/krisenmanagement/warnung-der-bevoelkerung

Kerzner, H. (2013). Project management: a systems approach to planning, scheduling, and controlling. *John Wiley & Sons*.

Koks, E., Van Ginkel, K., Van Marle, M., & Lemnitzer, A. (2021). Brief Communication: Critical Infrastructure impacts of the 2021 mid-July western European flood even. *Natural Hazards and Earth System Sciences Discussions*. https://nhess.copernicus.org/preprints/nhess-2021-394/nhess-2021-394.pdf

Mahdavian, F., Platt, S., Wiens, M., Klein, M., & Schultmann, F. (2020). Communication blackouts in power outages: Findings from scenario exercises in Germany and France. *International Journal of Disaster Risk Reduction*, *46*, 101628. https://doi.org/https://doi.org/10.1016/j.ijdrr.2020.101628

Mayer, J. (2017). Treibstoffversorgung bei Stromausfall-Empfehlung für Zivil- und Katastrophenschutzbehörden. In BBK (Ed.).

NDR. (2022). Stromausfall: Die Vorbereitungen in Städten und Landkreisen. Retrieved 2023-02-26, from https://www.ndr.de/nachrichten/niedersachsen/Stromausfall-Die-Vorbereitungen-in-Staedten-und-Landkreisen,stromausfall468.html

Ohder, C., Sticher, B., Benedikt, S., & Berlin, S. (2015). Katastrophenschutz-Leuchttürme als Anlaufstellen für die Bevölkerung in Krisensituationen. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwjsyu2jzLj9AhVGRPEDHSjfDl0QFnoECA4QAQ&url=https%3A%2F%2Fopus4.kobv.de%2Fopus4-hwr%2Ffiles%2F558%2FForschungsbericht_12.02.2016.pdf&usg=AOvVaw07xg0XRzZRyYjIWk-W31K7

OSCE. (2016). Protecting Electricity Networks from Natural Hazards. https://www.osce.org/files/f/documents/a/d/242651.pdf

Petermann, T., Bradke, H., Lüllmann, A., Poetzsch, M., & Riehm, U. (2011). What happens during a blackout - Consequences of a prolonged and wide ranging power outage. Retrieved 2023-02-02, from https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwjxlca8gLT9AhWAQvEDHUqVB0IQFnoECA8QAQ&url=https%3A%2F%2Fpublikationen.bibliothek.kit.edu%2F1000103292%2F122337755&usg=AOvVaw0N8GwD5jp2veV0zJFI-k66

Rhein, B. (n.d.). Rahmenempfehlungen zur Einsatzplanung des Brand- und Katastrophenschutzes bei flächendeckendem, langandauerndem Stromausfall. https://innen.hessen.de/sites/innen.hessen.de/files/2021-09/handlungsempfehlung_stromausfall_.pdf

Rubin, G. J., & Rogers, M. B. (2019). Behavioural and psychological responses of the public during a major power outage: A literature review. *International Journal of Disaster Risk Reduction*, *38*, 101226. https://doi.org/https://doi.org/10.1016/j.ijdrr.2019.101226

Saurugg, H. (2016). Meine Gemeinde auf ein Blackout vorbereiten. https://www.saurugg.net/wp-content/uploads/2015/08/Meine-Gemeinde-auf-ein-Blackout-vorbereiten.pdf

Searle, S. (2020). E-Fuels won´t save the internal combustion engine. Retrieved 2023-03-21, from https://theicct.org/e-fuels-wont-save-the-internal-combustion-engine/

TU Darmstadt. (2023). *emergenCITY*. Retrieved 2023-02-17 from https://www.emergencity.de/de/

Turner, J. R. (2014). The handbook of project-based management (4th ed.). *McGraw-Hill Education*.

UNDRR. (n.d.). Terminology - Disaster Management. https://www.undrr.org/terminology/disaster-management

Venable, J., Pries-Heje, J., & Baskerville, R. (2016). FEDS: a Framework for Evaluation in Design Science Research. *European Journal of Information Systems*, *25*(1), 77-89. https://doi.org/10.1057/ejis.2014.36

Weiß, U. (2003). Machbarkeitsstudien für regionale Projekte. *Raumforschung und Raumordnung*, *61*, 13-27. https://doi.org/10.1007/BF03183072

Witte, D., Bach, S., Lichte, D., Fiedrich, F., & Wolf, K.-D. (2021). *Functional Impact Analysis for Complex Critical Infrastructure Systems*. https://doi.org/10.3850/978-981-18-2016-8_280-cd

Appendix A – Interview Guide for Public Transport Companies in German

Einführung:

- Interview-Teilnehmer stellen sich vor
- Szenario Blackout wird vorgestellt
    - Relevanz und Aktualität, Überregionaler Stromausfall, Zeitspanne von 96h
- Forschungsmethode und Interview Ablauf werden vorgestellt

Block 1: Ist-Zustand der Zusammenarbeit mit dem Katastrophenschutz

1.1: Was würde Ihr Unternehmen in den ersten 96h eines Blackouts tun?

1.2: Welche Herausforderungen kommen auf Ihr Unternehmen während eines Blackouts zu?

1.3: Ist Ihr Unternehmen ein Tochterunternehmen der Stadt/des Landkreises? Ist die Stadt/der Landkreis Ihnen gegenüber weisungsbefugt?

1.4: Haben Sie bereits Erfahrungen in der Zusammenarbeit mit dem Katastrophenschutz? Benennen Sie relevante Erfahrungen, die auch auf einen potentialen Blackoutfall übertragbar wären.

Block 2: Hypothetische Zusammenarbeit mit dem Katastrophenschutz

2.1: Welche Ideen haben Sie durch die Ihr Unternehmen zu einer besseren Bewältigung einer Blackout-Lage beitragen kann?

- Welche Ressourcen sind für die Umsetzung dieser Idee bereits vorhanden?
- Welche Ressourcen werden für die Umsetzung noch benötigt?

Block 3: Machbarkeitsuntersuchung eines Konzeptes

3.1: Es wird Ihnen ein kurzes Konzept vorgestellt und ad hoc die Umsetzbarkeit hinsichtlich der folgenden Aspekte diskutiert. (Das Konzept wird erst während des Interviews erklärt, damit Ihre eigenen Ideen in Frageblock 2 dadurch nicht beeinflusst werden).

a. Organisation (Personal, Fahrpläne, Absprachen…)
b. Technik (Fahrzeuge, Verkehrsaufkommen, Betankung, Kommunikation…)
c. Finanzierung
d. Recht/Sicherheit
e. Mitbewirkungsbereitschaft/Akzeptanz (Organisation/Bevölkerung)

Abschluss

- Klärung offener Fragen
- Haben Sie Fragen vermisst? Gibt es Verbesserungsvorschläge?

Vielen Dank für Ihre Unterstützung. Für Rückfragen oder Anmerkungen stehe ich gerne zur Verfügung.

Appendix B – Interview Guide for Public Transport Companies in English

Introduction:

- Interview participants introduce themselves
- Blackout scenario is presented
    - Relevance, supra-regional power blackout, time span of 96h
- The research method and interview procedure are presented

Block 1: Actual state of cooperation with disaster management

1.1: What would your company do in the first 96h of a blackout?

1.2: What challenges does your company face during a blackout?

1.3: Is your company a subsidiary of the city/county? Does the city/county have authority over you?

1.4: Do you already have experience in working with disaster management? Name relevant experiences that would also be transferable to a potential blackout case.

Block 2: Hypothetical cooperation with the disaster management authority

2.1: What ideas do you have through which your company can contribute to a better management of a blackout situation?

- What resources are already available for the implementation of this idea?
- What resources are still needed for implementation?

Block 3: Feasibility study of a concept

3.1: A short concept is presented to you, and the feasibility is discussed ad hoc with regard to the following aspects. (The concept will only be explained during the interview so that your own ideas in question block 2 are not influenced by it).

a. Organization (staff, timetables, arrangements...)
b. Technology (vehicles, traffic volume, refueling, communication...)
c. Financing
d. Law/Safety
e. Willingness to participate/acceptance (organization/population)

Conclusion

- Clarification of open questions
- Did you miss any questions? Are there any suggestions for improvement?

Thank you very much for your support. Please do not hesitate to contact me if you have any questions or comments.

Appendix C – Interview Guide for Disaster Management Authorities in German

Einführung:

- Interview-Teilnehmer stellen sich vor
- Szenario Blackout wird vorgestellt
    - Relevanz und Aktualität, Überregionaler Stromausfall, Zeitspanne von 96h
- Forschungsmethode und Interview Ablauf werden vorgestellt

Block 1: Ist-Zustand der Zusammenarbeit mit dem Verkehrsunternehmen

1.1: Welche Maßnahmen würde Ihre Stadt/ Ihr Landkreis in den ersten 96 Stunden eines Blackouts treffen?

1.2: Welche Herausforderungen kommen auf den Katastrophenschutz während eines Blackouts zu?

1.3: Ist die Stadt/ der Landkreis dem Verkehrsunternehmen gegenüber weisungsbefugt? Gibt es bereits Absprachen zwischen dem Katastrophenschutz und dem Verkehrsunternehmen?

1.4: Haben Sie bereits praktische Erfahrungen in der Zusammenarbeit mit dem Verkehrsunternehmen? Benennen Sie relevante Erfahrungen, auch aus Übungen oder aus dem Krisenstab.

Block 2: Hypothetische Zusammenarbeit mit dem Verkehrsbetrieb

2.1: Welche Ideen haben Sie wie die Kooperation mit dem Verkehrsbetrieb zu einer besseren Bewältigung einer Blackout-Lage beitragen kann?

- Welche Ressourcen sind für die Umsetzung dieser Idee bereits vorhanden?
- Welche Ressourcen werden für die Umsetzung noch benötigt?

Block 3: Machbarkeitsuntersuchung eines Konzeptes

3.1: Es wird Ihnen ein kurzes Konzept vorgestellt und ad hoc die Umsetzbarkeit hinsichtlich der folgenden Aspekte diskutiert. (Das Konzept wird erst während des Interviews erklärt, damit Ihre eigenen Ideen in Frageblock 2 dadurch nicht beeinflusst werden).

a. Organisation (Personal, Fahrpläne, Absprachen…)
b. Technik (Fahrzeuge, Verkehrsaufkommen, Betankung, Kommunikation…)
c. Finanzierung
d. Recht/Sicherheit
e. Mitbewirkungsbereitschaft/Akzeptanz (Organisation/Bevölkerung)

Abschluss

- Klärung offener Fragen
- Haben Sie Fragen vermisst? Gibt es Verbesserungsvorschläge?

Vielen Dank für Ihre Unterstützung. Für Rückfragen oder Anmerkungen stehe ich gerne zur Verfügung.

Appendix D – Interview Guide for Disaster Management Authorities in English

Introduction:

- Interview participants introduce themselves
- Blackout scenario is presented
    - Relevance, supra-regional power blackout, time span of 96h
- Research method and interview procedure are presented

Block 1: Actual state of cooperation with public transport companies

1.1: What would your city/county do in the first 96h of a blackout?

1.2: What challenges does the disaster management authority face during a blackout?

1.3: Is the city/county authorized to issue instructions to the transport company? Are there already agreements between the disaster management and the transport company?

1.4: Do you already have experience in working with transport companies? Name relevant experiences that would also be transferable to a potential blackout case.

Block 2: Hypothetical cooperation with the public transport company

2.1: What ideas do you have on how cooperation with the transport company can contribute to better management of a blackout situation?

- What resources are already available for the implementation of this idea?
- What resources are still needed for implementation?

Block 3: Feasibility study of a concept

3.1: A short concept is presented to you, and the feasibility is discussed ad hoc with regard to the following aspects. (The concept will only be explained during the interview so that your own ideas in question block 2 are not influenced by it).

a. Organization (staff, timetables, arrangements...)
b. Technology (vehicles, traffic volume, refueling, communication...)
c. Financing
d. Law/Safety
e. Willingness to participate/acceptance (organization/population)

Conclusion

- Clarification of open questions
- Did you miss any questions? Are there any suggestions for improvement?

Thank you very much for your support. Please do not hesitate to contact me if you have any questions or comments.

Appendix E- Interview Guide for Research Experts in German

Einführung:

- Interview-Teilnehmer stellen sich vor
- Szenario Blackout wird vorgestellt
    - Relevanz und Aktualität, Überregionaler Stromausfall, Zeitspanne von 96h
- Forschungsmethode und Interview Ablauf werden vorgestellt

Block 1: Experten-Wissen

1.1: Welche Berührungspunkte haben Sie mit dem Thema Blackout?

1.2: Welche Herausforderungen bringt ein Blackout mit sich?

1.3: Welche Berührungspunkte haben Sie mit dem Thema Katastrophenschutz?

1.4: Welche Berührungspunkte haben Sie mit dem Thema Verkehrsunternehmen?

Block 2: Hypothetische Zusammenarbeit mit dem Katastrophenschutz

2.1: Welche Ideen haben Sie durch die ein Verkehrsunternehmen mit seinen Ressourcen zu einer besseren Bewältigung einer Blackout-Lage beitragen kann?

- Welche Ressourcen sind für die Umsetzung dieser Idee bereits vorhanden?
- Welche Ressourcen werden für die Umsetzung noch benötigt?

Block 3: Machbarkeitsuntersuchung eines Konzeptes

3.1: Es wird Ihnen ein kurzes Konzept vorgestellt und ad hoc die Umsetzbarkeit hinsichtlich der folgenden Aspekte diskutiert. (Das Konzept wird erst während des Interviews erklärt, damit Ihre eigenen Ideen in Frageblock 2 dadurch nicht beeinflusst werden).

a. Organisation (Personal, Fahrpläne, Absprachen…)
b. Technik (Fahrzeuge, Verkehrsaufkommen, Betankung, Kommunikation…)
c. Finanzierung
d. Recht/Sicherheit
e. Mitwirkungsbereitschaft/Akzeptanz (Organisation/Bevölkerung)

Abschluss

- Klärung offener Fragen
- Haben Sie Fragen vermisst? Gibt es Verbesserungsvorschläge?

Vielen Dank für Ihre Unterstützung. Für Rückfragen oder Anmerkungen stehe ich gerne zur Verfügung.

Appendix F – Interview Guide for Research Experts in English

Introduction:

- Interview participants introduce themselves
- Blackout scenario is presented
    - Relevance, supra-regional power blackout, time span of 96h
- Research method and interview procedure are presented

Block 1: Expert Knowledge

1.1: What points of contact do you have with the topic of blackout?

1.2: What challenges does a blackout pose?

1.3: What points of contact do you have with the topic of disaster management?

1.4: What points of contact do you have with the topic of transport companies?

Block 2: Hypothetical cooperation between the public transport company and the disaster management authority

2.1: What ideas do you have on how a cooperation can contribute to better management of a blackout situation?

- What resources are already available for the implementation of this idea?
- What resources are still needed for implementation?

Block 3: Feasibility study of a concept

3.1: A short concept is presented to you, and the feasibility is discussed ad hoc with regard to the following aspects. (The concept will only be explained during the interview so that your own ideas in question block 2 are not influenced by it).

a. Organization (staff, timetables, arrangements...)
b. Technology (vehicles, traffic volume, refueling, communication...)
c. Financing
d. Law/Safety
e. Willingness to participate/acceptance (organization/population)

Conclusion

- Clarification of open questions
- Did you miss any questions? Are there any suggestions for improvement?

Thank you very much for your support. Please do not hesitate to contact me if you have any questions or comments.