Strategic Objectives in Complex Planning Environments: *Insights from a Swedish Case for Critical Infrastructure Protection*

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To Charlotte.

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Abstract

Large-scale and long-term planning imposes extensive requirements on governance efforts regardless of whether it involves public organisations, private organisations, or both. The proportions of such planning entangle many actors and stakeholders as system components within and around a complex system. These system components and conditions in a complex planning environment introduce a diverse variety of strategic objectives into the planning. This study investigates how strategic objectives can affect the governance of complex planning systems, particularly in the context of national critical infrastructure protection. For this purpose, this thesis concentrates on a national planning procedure, *STYREL*, which Sweden has recently implemented for the case of power shortages. This case involves various actors from the national, regional and local levels who act on behalf of both public and private organisations in a planning process with four-year intervals, and it thus constitutes a relevant subject for this study. The investigation entailed the collection of evidence from documents and interviews. First, publicly available Swedish documents regarding the case provided an understanding of the planning. Second, interviews with decision-makers who are entrusted with this planning at municipalities and county administrative boards as well as with a few planners from power grid providers offered a deeper comprehension of both the proceedings in practice and the strategic objectives involved in this complex system for planning of critical infrastructure protection. Particularly, the findings resulted in several conceptual models that demonstrate these understandings in more detail. A soft system model visualises the problem situation and contains several elements, such as the system components, interrelations and conditions. Moreover, a multi-level planning model specifies sources of uncertainty in the planning and decision-making process that are associated with an insufficient alignment of strategic objectives in the *STYREL* case. These decompositions of the Swedish planning environment – both horizontal and vertical – further enabled this study to identify significant parameters of the systemic conditions and strategic objectives involved in such complex planning environments that challenge their governance. The findings of this study suggest that the Swedish process is not yet fully developed. The investigation particularly indicates that a better alignment of strategic objectives is necessary to ensure a selection of adequate goals and means that advances the future usability of the produced plan, which in turn would legitimate and strengthen this complex planning process for critical infrastructure protection.

Sammanfattning

Storskalig och långvarig planering ställer höga krav på styrning. Detta gäller oavsett om offentliga eller privata organisationer, eller båda, är involverade. Omfattningen av en sådan planering engagerar många aktörer och intressenter som komponenter inom och omkring ett komplext system. Dessa komponenter samt deras villkor inbäddade i en komplex planeringsmiljö skapar en mångfald av strategiska målbilder som följer med in till planeringen. Denna studie undersöker därför hur strategiska målbilder kan påverka styrningen av komplexa planeringssystem, särskilt i kontexten av skyddet av kritisk infrastruktur i samhället. Undersökningen fokuserar på en nationell planeringsprocess, kallad *STYREL*, som avser beredskapsplanering för elbristsituationer och som implementerats i Sverige. Planeringsmiljön omkring *STYREL* är ett relevant studieobjekt eftersom den involverar många aktörer från nationell, regional och lokal nivå. Dessa aktörer representerar offentliga och privata organisationer i den planeringsprocess som genomförs med fyraårsintervaller. Under undersökningens gång har bevis samlats in från dokument och intervjustudier. Först har offentlig tillgängliga dokument om fallet skapat en förståelse om planeringen. Intervjuer med beslutsfattare som är ansvariga för *STYREL*-planeringen hos länsstyrelser, kommuner samt elnätsbolag har sedan genererat en ännu djupare förståelse. Detta gällande både förfaringssättet i praktiken och de strategiska målbilder som är involverade i detta komplexa system för planering av kritisk infrastruktur-skydd. Resultaten ledde i synnerhet till några konceptuella modeller vilka demonstrerar förståelserna på ett detaljerat sätt. En systemmodell visualiserar problemsituationen och innehåller flera element såsom systemkomponenter, relationer och villkor. En multinivå-planeringsmodell specificerar källor av osäkerhet i planerings- och beslutsprocessen vilka är associerade med en otillräcklig harmonisering av strategiska målbilder i *STYREL* fallet. Dekompositionerna av den svenska planeringsmiljön – både horisontellt och vertikalt – gjorde det möjligt att identifiera signifikanta parametrar av de systemiska villkor och strategiska målbilder som är involverade i dessa komplexa planeringsmiljöer och utmanar deras styrning. Resultaten av studien indikerar att den svenska processen inte är fullt utvecklat. Undersökningen visar att en bättre harmonisering av strategiska målbilder är nödvändig för att säkerställa ett urval av adekvata mål och medel som skulle utveckla den framtida användbarheten av den producerade planen. Denna skulle i sin tur legitimera och stärka den komplexa planeringsprocessen för skyddet av kritisk infrastruktur. Därtill kunde detta främja en målgruppsorienterad kommunikation om risker och relevanta åtgärder.

List of Papers

I. Große, Christine; Olausson, Pär M.; Danielsson, Erna; Larsson, Aron; Wallman-Lundåsen, Susanne; Björkqvist, Olof; Nyhlén, Jon (forthcoming), *Collaboration and Decision-making in Response Planning for Power Shortages: The Swedish Policy*. Under Review at an International Journal.

II. Große, Christine (2017), *Applying Systems Thinking onto Emergency Response Planning: Using Soft Systems Methodology to Structure a National Act in Sweden*. In: Proceedings of the 6th International Conference on Operations Research and Enterprise Systems (ICORES), pages 288-297. DOI: 10.5220/0006126202880297.

III. Große, Christine (forthcoming), *Sources of Uncertainty in Swedish Emergency-Response Planning*. Under Review at an International Journal.

IV. Große, Christine (2017), *Research in Complex Planning Situations: Dimensions and Challenges from Swedish Response Planning*. In: Proceedings of the 16th European Conference on Research Methodology for Business and Management Studies (ECRM), pages 432-440.

Keywords

Systemic Thinking, Soft Operations Research, design-oriented Information Systems Research, Governance, Complex Systems, Critical Infrastructure Protection, Largescale Planning, Multi-level Planning, Strategic Management

1 Introduction

Chapter 1 explicates the research topic in the field of complex systems and the context of critical infrastructure protection and it specifies the structure of the thesis. The chapter first motivates governance of complex planning systems as the focus of this thesis and emphasises strategic objectives as a specific aspect of governance. Second, it notes the purpose, aim and research questions in order to concretise the direction of the inquiry. Finally, the outline of the thesis completes the introduction.

1.1 Motivation

The growing interconnectedness of modern societies has increased their dependency on vital societal functions, such as electricity, heating, water supply, healthcare services, the Internet and other communication technology (Johansson et al. 2014; Roukny et al. 2016). Recently, public and private organisations as well as governments have recognised the vulnerability that is associated with this dependency because exploiting this vulnerability could result in catastrophic consequences (Buldyrev et al. 2010; Boin, McConnell 2007; Rinaldi et al. 2001; European Commission 2004a, p. 8). The protection of infrastructure that is critical to society's functionality, survival and progression (Cohen 2010) has therefore gained significance for national security in many countries and for research in this area (Birkmann et al. 2016; BMI 2009; Canada 2009; European Commission 2004b; MSB 2011). Critical infrastructure has been characterised as a complex adaptive system in view of the interconnectedness of system components, the non-linearity of consequences and the adaptive behaviour and extent of the system (Hokstad et al. 2012; van der Lei et al. 2010). In accordance with Ashby, the protection of such critical infrastructure can be considered a similarly complex system (Ashby 1956). Critical infrastructure protection (CIP) consists of analysis and planning as well as implementation and monitoring of measurements for prevention, protection and restoration. The co-ordinated execution of these entangled processes for national CIP necessitates interaction, collaboration and communication among the various actors from public and private organisations with the aid of formal and informal structures and technology. Hence, planning for CIP is a complex system of actors and interrelations that fulfil a certain purpose beyond the capabilities of the individual sub-systems. Such circumstances are of primary interest for the field of complex systems.

Moreover, this non-linearity of cause and effect due to interconnected sub-systems can evoke an emergent system behaviour, which the properties of the sub-systems cannot completely explain (see e.g. Bar-Yam 2009). Research on

complex systems further concerns governing dynamics and multi-dimensional problems, which invokes complex system governance to produce system viability through control, communication, co-ordination and integration (Keating 2014; Keating, Bradley 2015; Keating et al. 2015). One such problem is that the planning for CIP includes analyses of consequences that it may have on a modern society in the case of a certain risk event, such as an electrical blackout (Buldyrev et al. 2010; Johansson et al. 2014; Pescaroli, Alexander 2016; Utne et al. 2012). However, the openness and extent of complex systems challenge not only the comprehensive definition of the term '*complex*' (Hayek 1967; Horgan 1995) and '*system'* (e.g. Bertalanffy 1968; Mandel 2010) but also the analysis, modelling and governance of complex systems due to the multitude of factors that contribute to the problem. The reduction of system complexity is therefore a subject of discussion in the field. Approaches span from dividing such systems into parts to examine them separately to reducing the extent of the system to the most simple working model, which is computable for a particular phenomenon without separating the elements, and further to systems thinking that encourages a holistic view of a system or problem (Ackoff 1999; Avison, Taylor 1997; Checkland 1989; Stachowiak 1973; Sterman 2006). The reduction of problem complexity facilitates analysis, model building and governance of complex systems (Rosenhead, Mingers 2008). In the context of national CIP, a holistic perspective of the complex system appears to be preferable since governance of such systems necessitates an alignment of goals and means of the involved sub-processes for protecting modern societies. Efforts towards such an alignment need to acknowledge properties of complex systems, but not only from a purely technical perspective. Evolving from physics and biology to modern information and communication technology, the term '*complex system*' has acquired a predominantly technical character; therefore, the development of mathematical models and software solutions for simulating system behaviour has been at the forefront of research in the field of complex systems and their governance. Nevertheless, the strategic objectives that are involved in the large-scale, socio-technical, adaptive systems that deal with national CIP challenge further governance of such complex systems and their environment (e.g. Adelt et al. 2014; Hassel, Cedergren 2017; McGee, Edson 2014; Nagel, Wimmer 2003). Due to this special need in the research field, the summary particularly addresses challenges that strategic objectives pose for the governance in complex planning environments, such as national CIP. This study predominantly uses the term '*complex planning environment'* in order to avoid confusion with hardware and software solutions for planning.

Critical infrastructure protection involves sensitive information about certain vulnerabilities of a nation or business, which may explain why discussions in literature are limited to only a few cases, such as Canada's approach to CIP (Quigley 2013). Germany has recently acknowledged the importance of such planning and initiated the enhancement of civic defence by elaborating on a concept regarding emergency power, among taking other measures (BMI 2016). However, there is a notable absence of concrete descriptions of these complex systems and their parts and interrelations as well as of the proceedings during planning processes. To address this, the research in this thesis examines a Swedish approach for CIP, namely *STYREL*, which is dedicated to creating an emergency response plan for power shortages. Sweden implemented this case of a complex system in 2010/2011 and has executed the multi-level planning process *STYREL* on two occasions. Due to the advanced stage of this complex system, a representation of the Swedish case is of major interest to research on complex systems, governmental policy makers and practitioners in the field of CIP or similar contexts.

1.2 Purpose and Aim

As mentioned, planning for CIP involves collaboration among many actors to protect national interests and society, which renders it similar to international, national, regional or local responses to an emergency. In these circumstances, the complex planning system involves highly interconnected sub-systems whereby interests can cross internal system boundaries and consequences of interdependencies can also occur stochastically as non-linear (Renn 2016). Such system conditions necessitate both strategy and leadership that maintain system viability (Denhardt, Denhardt 2011) – understood as governance – to approach the planning tasks. Therefore, the purpose of this investigation is to explore challenges that governance must contend with in the context of such complex planning systems and their environments in order to address current social developments of CIP and inform research in complex systems governance. For this purpose, the study concentrates on *STYREL*, the Swedish emergency response planning for power shortage events.

The aim of this study is twofold. On the one hand, it intends to provide knowledge that can generate context for a constructive dialogue about strategic objectives that are involved in complex planning environments, such as in emergency response planning for CIP. On the other hand, the study seeks to establish a comprehensive representation of the Swedish *STYREL* case through a detailed description, analysis and modelling of the complex system of planning for CIP during power shortages.

1.3 Research Questions

Through a holistic system perspective of the complex planning environment, this study examines the following research questions, which concretise the outlined direction, purpose and aim of the study.

RQ 1: Which conditions represent the complex system of response planning for power shortages and its environment of CIP in accordance with STYREL in Sweden?

RQ 2: Which sources of uncertainty and strategic objectives emerge from multi-level planning in general and from the complex system of emergency response planning for CIP and the interrelated STYREL process in Sweden in particular?

RQ 3: How do the implications of these systemic conditions and strategic objectives affect governance of the complex planning for CIP in Sweden?

1.4 Structure of the Thesis

This article-based licentiate thesis is a compilation of four scientific research articles (Paper I – IV, see the Appendix) and a summary of these publications. The summary at hand embraces and extends beyond the scope of the included articles in order to present a more comprehensive perspective of the topic.

Subsequent to this introduction, the remainder of the thesis is organised as follows. Chapter 2 defines the background of the investigation. Besides briefly introducing the case of *STYREL*, it presents the holistic system perspective that underpins the study's focus on governance and the role of strategic objectives in complex planning environments. It also describes the power-supply context in the problem area of CIP. Chapter 3 debates epistemological, methodical and ethical issues associated with this inquiry and its subject, which establishes the basis for the further proceedings of the study. Chapter 4 first provides a thorough description of the Swedish planning case followed by an overview of results from both the summary and the included papers. Moreover, it analyses their contribution to the research questions and synthesises the insights into a conceptual framework that generates a context for a constructive dialogue about strategic objectives in complex planning environments. Chapter 5 discusses implications of the results for the Swedish and similar cases in practice and for relevant research areas and academia. Furthermore, it highlights limitations of the applied research approach. Thereby, Chapter 5 signifies the contributions of this study and indicates opportunities for future research. Chapter 6 briefly summarises the thesis and notes key insights and contributions. The conclusions highlight the study's achievements and encourage further proceedings.

2 Concepts, Theories and Context

Chapter 2 contextualises the case and presents concepts from literature as well as some technical background associated with the power supply. The sections provide terms that are relevant for this study without extensively discussing terminology. Thereby, theories and terms specify the research field in general and the problem area in particular and shape the theoretical framework for this study. This framework leads the operationalisation during this summary and encompasses the included papers; each paper concretises its particular angle for approaching a given aspect of the subject.

2.1 Background of the Swedish Case – *STYREL*

The complex system that this study investigates in detail surrounds and executes a planning process in Sweden called *STYREL*. This process was developed between 2004 and 2011 and was executed 2010/2011 and 2014/15 (SEA 2014). It applies a four-year interval and intends to plan for emergency response to power-shortage situations in Sweden, and it involves many actors from the local, regional and national levels (see Table 5, p. 29 for details). This planning is part of the Swedish Crisis Management System and aims to proactively enhance preparedness (MSB 2011). The process relies on collaboration among actors from public and private organisations and on highly limited technical support for decision-making, information processing and communication. Many actors represent the executing body, including various national agencies, county administrative boards (CABs) as regional co-ordinators, municipalities as holders of local knowledge, and individuals as decision-makers, upon a ranking list of prioritised power consumers. Furthermore, all power grid providers participate in the complex planning approach of *STYREL*, which aims to identify and prioritise power consumers that provide society with critical services. The communicated objective behind the approach is to reduce the negative consequences of power shortages for society. The Swedish case is therefore an interesting example of potential competing interests in such a complex system of planning for CIP and is accordingly relevant well beyond the Swedish context.

The *STYREL* approach is seemingly a unique process of planning for CIP, as the scientific literature does not discuss similar planning processes. A major electrical blackout in southern Sweden in 2003 was the initial trigger for the development of the complex system under investigation. The 2003 blackout was due to the tripping of a unit at a nuclear power station shortly followed by a major fault in a substation. After 90 seconds, this caused a blackout in southern Sweden that also spread consequences to eastern Denmark. The

power grid providers restored the current stepwise and completed the restoration after 10 hours. Although both national power grid operators considered the co-operation to be reliable, the Danish report identified technical, managerial and policy-related issues, such as a need to revise the principles for restoration '*with a view to ensuring the right order of priority for disconnection and reconnection of consumers*' (Elkraft System 2003, p. 6). (Elkraft System 2003; Larsson, Danell 2006; Larsson, Ek 2004; Svenska Kraftnät 2003)

The continued relevance of such planning for CIP as in the Swedish *STYREL* case is also apparent in the most recent major blackout in Turkey in 2015. During this event, the majority of Turkey experienced an electrical blackout 12 seconds after the initial event that was due to several cascading effects. Fortunately, this outage did not affect neighbouring countries, and the official report stated only minor effects on critical infrastructure since it mostly possessed its own emergency power during the outage. The system was restored after 10 hours (ENTSOE 2015).

In view of such power supply disturbances, studies have investigated the reliability of power transmission (Alvehag, Söder 2011; Münzberg et al. 2014) and how to address cascading failures in power systems (Vaiman et al. 2013). Other research has shown how to facilitate power system restoration (Barsali et al. 2008; Soman et al. 2015; Tortos, Terzija 2012) but has done so from a purely technical perspective, which ignores any after-effects on national society. Such further impacts are likely to emerge since the power sector is central to other belonging sectors of critical infrastructure (Rinaldi et al. 2001), where cascading failures due to interdependencies in urban settings can have serious consequences (Hines et al. 2009). Some studies have therefore been further concerned with the potential impact of climate changes on power supply and have predicted moderate-to-severe consequences (Bardt et al. 2013; Bartos, Chester 2015). Boin and McConell (2007) have consequently acknowledged the limits of national planning for CIP and have identified a societal need to enhance resilience. In addition, national regulations and policies have been considered to provide implications for power supply and for potential consequences of an outage (Goldman et al. 2002; Johnson 2006), while the electrical system as transnational infrastructure brings challenges to the governance of such a complex system due to various strategic interests (van der Vleuten, Lagendijk 2010).

The above considerations position the complex system that surrounds and executes the complex *STYREL* planning process in Sweden as a case of major interest to research in complex systems, governmental policy makers and practitioners in the field of CIP and similar contexts, including and beyond the Swedish case.

2.2 System and Environment of Complex Planning

The system perspective in general and the governance of complex planning environments in particular shape the lens of investigation for this study. Strategic objectives emerge as preconditions that governance must consider.

2.2.1 A System Theoretical Perspective

The concept of a system can effectively describe complex planning environments. Systems can generally be perceived as components that interact (Bertalanffy 1968, p. 33), though interactions do not necessarily occur only between components but are also present with the system environment. Open systems specifically interact across and beyond system boundaries with other systems or with a larger, surrounding environment (Bertalanffy 1968, p. 141). This study prefers the term ***'complex planning environment'***, which draws attention to the openness of the system, because the boundaries of the Swedish system, which embraces the *STYREL* process, are fluid and adapt to emerging changes, such as the number of components, their behaviour or requirements.

Considering the adaptability of the *STYREL* approach, complex planning environments can be further conceptualised as complex adaptive systems (Hokstad et al. 2012; van der Lei et al. 2010). Such systems describe components as interacting in parallel, basing actions on conditional reasoning, building subroutines and using adaption to improve performance (Holland 2006). These components can additionally be interpreted as actors who belong to their particular context as a social (sub-) system. The large number of actors, which Table 5 indicates, and the information flow among them within their distributed environment particularly stress the complexity of the system that is examined below (Boulding 1956, pp. 202–205; Kearney, Kruger 2016). In association with this adaptability, changing circumstances of the *STYREL* planning with regard to organisational requirements, personnel changes and societal developments, for example, have raised incalculable chains of cause and effects. This non-linearity due to the interconnectedness of sub-systems can lead to emergent and unpredictable behaviour of a complex system that challenges its governance.

Information systems research has characterised complex planning environments as socio-technical systems with reference to the argument that a system for CIP consists of people, information and communication technology, organisational concepts and the interconnections between them (Österle et al. 2011). Emery and Trist (1960, p. 86) have argued that the socio-technical system as a holistic system is able to achieve a better outcome compared to the parts standing alone. Mumford (2006) has further appraised the ability of the human as part of the socio-technical system to improve the

system and recognise its value. However, it is not only the components but also their interactions with a surrounding environment that are essential in complex planning environments when recognising them as socio-technical systems. The quality of these interactions appears to be relevant for proper information exchange and security (Scholl et al. 2017; Street 2016). Thus, this information exchange gains importance for the governance of the complex system of planning for CIP, and it requires an alignment of strategic objectives in order to develop information processing that is secure and adequately usable within the socio-technical system, and even across system boundaries.

Diminishing the boundaries in complex planning environments invites further perspectives from other concerned stakeholders. Such a system perspective includes all stakeholders interrelated with the planning problem (Axelsson et al. 2013; Keeney, McDaniels 1999; Reed et al. 2009). Applying such a perspective of complex planning systems for CIP that are similar to that which this study examines would include both types of stakeholders: those that are involved in the *STYREL* planning process and those that are not directly involved but may still be affected by its consequences.

There are additional concepts, such as sociomateriality, that are interrelated with complex systems but not specifically considered in this study. Current discussions of concepts and theories highlight their importance for systems science, information systems research and business information systems engineering (Bichler et al. 2016a, 2016b; Demetis, Lee 2016, 2017; Mingers 2017; Robey, Abdalla Mikhaeil 2016; Schultze 2017; WKWI 2011).

The Process in the System

A process is a content-related and self-contained sequence of timely and logically consistent events and activities that processes a central, process-characterising object (see e.g. Becker, Schütte 2004; Davenport, Short 1990; Davenport 2017; Scheer 1991). In the context of this study, the planning process *STYREL* meets two interpretations. First, it is a process as defined above during a particular execution. Second, it serves as a reference process for future iterations and similar planning in other application areas, such as planning for CIP in other countries or sectors (e.g. vom Brocke 2002). In both interpretations, the process relies on an executing system; the system can exist independently of the process realisation but may adapt to changes.

With regard to *STYREL*, several interrelations of structure and impact shape the complex system to investigate (Krallmann et al. 2013). These are as follows:

(1) Interrelations between events and activities of the process
(2) Interrelations between (1) and individuals/organisations that realise (1)
(3) Interrelations between (1), (2) and the process object

(4) Interrelations between (1) – (3) and tools, such as information and decision-support systems
(5) Interrelations between (1) – (4) and a reference process development
(6) Interrelations between the *STYREL* process (1) – (4) and belonging processes for CIP and preparedness and continuity planning
(7) Interrelations between the *STYREL* process (1) – (4) and the implications for the affected but non-participating society
(8) Interrelations between interests that are involved in (1) – (7)

In summary, this study applies a holistic system perspective to the complex system that is concerned with *STYREL*. This system involves components, their interrelations and systemic conditions. All of these parts provide specific characteristics to governance, which this study investigates in the complex planning environment interrelated with Swedish CIP.

2.2.2 Governance in Planning

In the complex and quickly changing environments that are indicated above, collaboration and strategy development are crucial for meeting future challenges (McGuire 2006; Poister 2010). Therefore, planning can be regarded as central for activities that develop strategies and processes in public and private organisations.

The task of planning emerges when a situation is perceived to be problematic or worthy of improvement (Checkland 2008) and a new future state is favoured. Planning therefore pursues such intended goals by elaborating on appropriate means (Christensen 1985). In a narrow sense, planning prepares the basis for decision-making, whereas in a broader sense, it also includes the decision-making process. Klein and Scholl (2012, p. 2) have provided a definition that illustrates the correlation as indicated above:

> '*Planning is a fundamentally systematic and rational process based on (mostly) incomplete information performed by planners for solving decision problems under consideration of subjective representation of goals*.'

This subjectivity, which is associated with a definition of goals, warrants special consideration in an organisational context, wherein the views of stakeholders – involved and affected – need appropriate attention. Mintzberg has questioned the particular impact that an individual can pose to strategy development and planning (1994). The current example of Donald Trumps' decision-making upon changes to U.S. environmental policy may illustrate that such impact is still a valid matter of concern (cf. e.g. Greshko et al. 2017).

Moreover, complex organisational settings, such as those which involve many individuals and groups in planning within a distributed or joint environment, provide further challenges to collaborative agreements on goals

and pathways towards strategic plans due to differing levels of experience and influence that are entangled with the planning (Stasser et al. 2015).

Hence, the aforementioned challenges for strategy development and planning demand an alignment of goals and a co-ordination of means for reaching a future state that is jointly preferred in such a multi-level planning as national planning for CIP. Defining this jointly preferred state, aligning strategic objectives and co-ordinating appropriate means necessitate controlling activities subsumed as governance. According to Lovan et al., governance is concerned with '*processes of making decisions*' and particularly involves the '*distribution of public responsibilities across multiple stakeholders*' which interact '*both as individuals and as participants with mutual interests*' (2016, pp. xv-xvi).

This definition implies that governance addresses both direct leadership and communication among individuals and groups (Denhardt, Denhardt 2011) and the indirect meta-level that policies and control provide (Whitney et al. 2015). Hence, two dimensions of governance are identifiable with respect to complex and multi-level planning. The first dimension, which is *horizontal*, concerns the alignment and co-ordination of means and activities in structured processes towards determined goals. The second dimension, *vertical*, addresses the alignment and co-ordination of strategic objectives within a system of systems. Therefore, governance also addresses the resolution and dissolution of conflict situations for integrating various objectives in a complex environment that plans for CIP. In association with these two dimensions of governance, a similarly co-ordinated information flow – horizontal and vertical through the system – has been considered vital for communication and co-operation among interconnected system components (e.g. Quigley 2013; Watzka 2017b). In prolongation, this information flow consequently gains significance for the alignment and co-ordination of strategic objectives in complex planning environments.

From the aforementioned stakeholder perspective, governance in a complex planning environment for CIP must also consider objectives that other stakeholders may raise. Such stakeholders may not directly participate in the planning but can be affected by its consequences; one example is the majority of civic society, which may suffer from the consequences of a national electrical blackout. Apart from the difficulty of involving all conceivable stakeholders in nationally or internationally planning for CIP, not all strategic objectives may be achievable. Therefore, the challenges that governance encounters require close attention in complex planning environments (Birkmann et al. 2016; McGee, Edson 2014) in view of the systemic conditions of the planning and the properties of the involved strategic objectives.

2.2.3 Characteristics of Strategic Objectives

Strategic objectives are preconditions to all planning regardless of whether it concerns issues in the personal sphere or in business or public environments. They precede the operational objectives of a complex planning system, while both precede process goals (Bouckaert, van Dooren 2010, p. 153). Depending on the complexity of the issue, many strategic objectives can be involved either consciously or unconsciously. The number and variety of these strategic objectives increase with the type and extent of a planning project, and they grow as more stakeholders or groups with partly divergent objectives become concerned and as the interconnectedness of these interests and stakes in such project becomes unclear (Christensen 1985; Renn 2016; Roukny et al. 2016). To enable planning to concentrate on the favoured objective(s), governance assumes a special significance in complex planning environments, such as planning for CIP. Since the boundaries between prevention, emergency response and restoration are fluid in such complex planning, governance must place an even greater emphasis on the challenges that strategic objectives pose to national planning for CIP as a result of their variety and diversity.

Although planning depends on strategic objectives, such objectives may appear vague, especially in the early stages of planning. This ambiguity emerges from ***implicit*** objectives, which involved stakeholders bring into the planning. These implicit objectives exist subconsciously as concerns and derive from learned patterns and the *Weltanschauung* of an individual (Checkland 2008; John Locke 1824; Schultze-Kraft et al. 2016). In addition, an individual understanding of *morally good conduct* (see 3.1) combined with personal circumstances accompanies a particular stakeholder. Given the number of stakeholders – both those who are involved and those who are affected – complex planning environments need to take these implicit objectives into account. For this purpose, governance can attempt to convert implicit objectives into ***explicit*** objectives by formulating and concretising the tacit content and its importance (Śliwa, Patalas-Maliszewska 2015). Apart from difficulties that may arise alongside this conversion process for a single person, the process of concretely defining explicit objectives becomes more complicated as more stakeholders become involved. This complex conversion process may require several iterations of refinement with regard to measurability, time horizon and responsibilities that are associated with the content and meaning of strategic objectives in a complex planning environment (Mariño, Boland 1999).

Both implicitly understood and explicitly formulated strategic objectives can further interact. While some strategic objectives can be interpreted as ***intermediate*** towards more evolved ones, i.e. ***advanced*** strategic objectives,

these are subject to additional logical and formal relations (Watzka 2017a).

From a logical perspective, such objectives could be identical, compatible or antinomic, i.e. mutually incompatible. ***Identical*** strategic objectives have the same content and meaning but are labelled differently. In complex planning environments for CIP, the identification of such identical objectives can enhance communication about them. Dissolving these identical objectives may mitigate the ambiguity in such planning. In contrast, an antinomy of strategic objectives signifies an insurmountable discrepancy between them. Therefore, apart from identifying these ***antinomic*** strategic objectives, governance must analyse and decide between them since they are, per definition, not simultaneously achievable. (Thommen et al. 2017)

A formal perspective can further assess ***compatible*** strategic objectives. From this view, objectives – and especially the means to reach them – can present side effects for each other. These side effects can be classified as beneficial, neutral or conflicting. Means with ***beneficial*** side effects support the simultaneous achievement of objectives other than the initially intended one. Side effects that do not influence the achievement of other objectives are considered to be ***neutral***. In contrast, goal-oriented means can have side effects that impair the simultaneous achievement of multiple strategic objectives. Such ***conflicting*** side effects complicate the governance of complex planning environments because a decision about preferred strategic objectives demands compromise between strategic objectives and appropriate means to pursue them. (Ramb 2017)

Figure 1 depicts the structural composition of the properties that strategic objectives interrelate with complex systems and their governance.

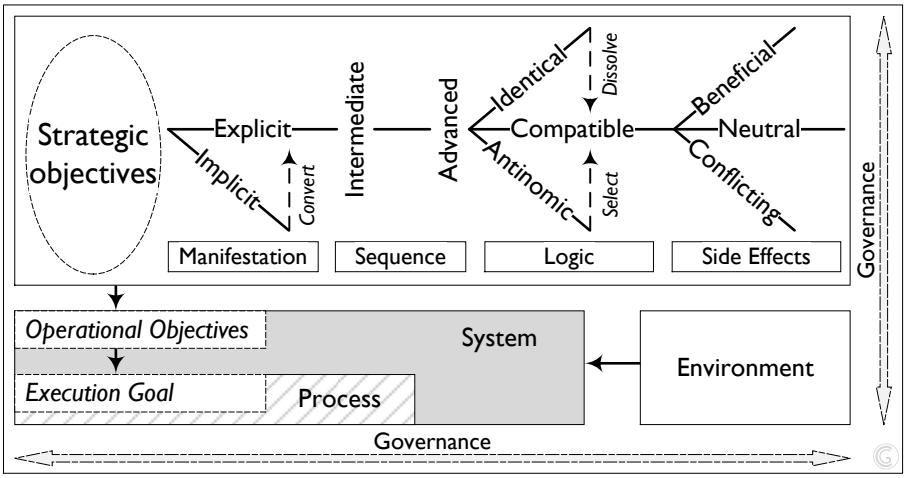

Figure 1: Characteristics of Strategic Objectives
(Source: Own representation based on Bouckaert, van Dooren 2010, p. 153)

2.3 Critical Infrastructure Protection

This section concretises the problem area and introduces CIP as a complex planning environment. Furthermore, it narrows the context of the inquiry to the central sector of critical infrastructure, namely the power supply.

2.3.1 Critical Infrastructure and Protection

The term 'infrastructure' stems from the Latin words *infra,* meaning 'underlying', and *structura,* meaning 'assemblage'. Infrastructure is thereby defined as an underlying base or framework. Adaptation of this underlying framework to suit a nation necessitates specification of the included parts. Buhr has argued that a country's infrastructure system consists of a combination of material, institutional and personnel infrastructure (Buhr 2009, p. 40):

- The *material* component mainly contains the physical infrastructure. It serves the basic needs of economic agents, both physical and social, that would otherwise be unavailable.
- The *personnel* infrastructure represents the part of working population that relates to the material component.
- The *institutional* infrastructure encompasses formal rules and informal constraints that are essential for the economic operation. In addition, it includes public and societal procedures.

Thus, infrastructure is a '*socio-technical system-of-systems*' (Gheorghe et al. 2006, p. 4) which includes all elements, relations and rules that drive the system. The personnel aspect is particularly relevant as a reference point for infrastructure. In correlation to this aspect, infrastructure becomes critical if people directly or indirectly depend on the continuity of these structures for survival and for progress in a period (Cohen 2010). With this interdependency, various strategic objectives emerge from the perspective of the concerned people. Globalisation introduces further challenges and amplifies the complexity of critical infrastructure because the growing dependence on an interconnected world increases the vulnerability of modern societies (EC 2004a, p. 8). Official institutions offer several definitions of the complex term '*critical infrastructure*'.

- The European Commission has defined critical infrastructure as structures that *'consist of those physical and information technology facilities, networks, services and assets which, if disrupted or destroyed, would have a serious impact on the health, safety, security or economic well-being of citizens or the effective functioning of governments in the Member States. Critical infrastructures extend across many sectors of the economy, including banking and finance, transport and distribution, energy, utilities, health, food supply and communications, as well as key government services. Some critical*

elements in these sectors are not strictly speaking 'infrastructure', but are in fact, networks or supply chains that support the delivery of an essential product or service. For example the supply of food [...] is dependent on some key facilities, but also a complex network of producers, processors, manufacturers, distributors and retailers' (EC 2004b, pp 3-4). The referenced document also states the nine sectors indicated in the definition.

- The government of Canada has similarly defined critical infrastructure: '*Critical infrastructure refers to processes, systems, facilities, technologies, networks, assets and services essential to the health, safety, security or economic well-being of Canadians and the effective functioning of government. Critical infrastructure can be stand-alone or interconnected and interdependent within and across provinces, territories and national borders. Disruptions of critical infrastructure could result in catastrophic loss of life, adverse economic effects, and significant harm to public confidence'* (Canada 2009, p. 2). It has identified 10 sectors of critical infrastructure to address.
- The German Federal Ministry of the Interior has concisely defined critical infrastructure as follows: '*Critical infrastructures (CI) are organizational and physical structures and facilities of such vital importance to a nation's society and economy that their failure or degradation would result in sustained supply shortages, significant disruption of public safety and security, or other dramatic consequences'* (BMI 2009, p. 4). The policy subsequently specifies nine sectors to consider nationally.
- The Swedish Civil Contingencies Agency (MSB) has defined critical infrastructure as '*physical structure whose functionality contributes to ensure the maintenance of important functions of the society*' (MSB 2011, p. 6). In addition, the referenced document defines the social functions, which have significance for society and are associated with 11 sectors.

These partly varied perspectives of critical infrastructure reflect not only the multi-faceted nature of the term '*critical infrastructure*' but also the complexity of planning for CIP both within a national system and across country borders (Masera et al. 2006a).

The above definitions imply that a differentiation between physical structures and social functions, which include the institutional and personal aspects, is unrewarding. In addition, it becomes difficult to separate a social function from the interrelated society without considering physical infrastructure, such as roads. Hence, such separate treatment involves unintended redundancy. A holistic view of the critical infrastructure 'system-of-systems' is rather suggested not only in regard to European conventions but to harmonise perceptions among decision-makers, who are entrusted with

planning for CIP (Pescaroli, Alexander 2016). Even though consideration of critical infrastructure as described above may allow decision-makers to realise the intended meaning, determining the extent to which one specific asset or power consumer is critical for society has proven much more difficult (Fekete 2011). Planning for CIP first needs to identify and assess interdependencies between infrastructure assets, such as power consumers, and the society or parts of it, which could include industries or citizens (Fekete et al. 2012). Then, further analysis can explore consequences of these interdependencies. However, estimations of consequences are highly uncertain as a result of both the limited availability of historical events to use as references and the progression towards a more digitalised and interconnected society (Johansson et al. 2014; Roukny et al. 2016).

For instance, due to the central role of the power distribution system in a complex system of critical infrastructure, the case of a critical power shortage is likely to provide cascading effects that pose severe consequences for society (Hines et al. 2009; Vaiman et al. 2013). Therefore, a plan for mitigating the impacts of future power shortages must take into account the interests of concerned stakeholders, such as national governments, public and private organisations, and civic society and individuals (Aven, Renn 2009). Such a holistic system view may in turn facilitate governance efforts in order to align strategic objectives within the complex planning environment for CIP.

2.3.2 Protection of Power Supply

As mentioned, the power supply is crucial to the critical infrastructure network (Yusta et al. 2011). Since other infrastructure largely relies on the availability of electricity, the power supply holds a key position among the interdependent sectors of critical infrastructure (Rinaldi et al. 2001).

Although electricity is now essential for modern society, the demand for a power supply at any time must confront physical challenges. Electricity has so far been difficult to store but provides good transfer properties. Therefore, engineers started the development of power grids 130 years ago (Schufft 2007b). Such power grids transfer electricity from power production sites to power demand sites. In Sweden, for example, the majority of power production occurs in the north, while most of the demand is concentrated in the southern region of the country. To bridge this long distance with a low electricity load loss, high-voltage overhead power lines constitute the main, national power grid, which supplies electricity to lower-voltage grids, in this thesis referred to as regional and local power grids. Similarly to other power networks, the Swedish power grid must manage the grid frequency within the network to prevent blackouts (Boemer et al. 2011).

Grid frequency maintenance involves continuously balancing production and consumption to ensure the stability of network conditions. However, in all sub-systems alongside the power supply – namely the production, distribution and consumption of electricity – disturbances can emerge. Apart from natural or weather-induced events, such as storms or falling trees, such disturbances can also be caused by the aging of components (Schufft 2007a). Human error, which resulted in a two-hour blackout in central Europe in 2006 (UCTE 2006), or cyber attacks, such as recently reported from Ukraine (ICS-CERT 2016), are additional origins of disturbances. Electrical installations contain various protection systems to prevent humans and devices from experiencing damage. Such local protection systems respond quickly to the cause of failure; however, even a local protection can have significant repercussions for power grid balance depending on the amount of electricity that is severed (Masera et al. 2006b). Therefore, disruptions associated with consumption require an electricity-feed reduction, whereas disruptions in production demand a reduction of consumption. Disturbances of the power grid can thus require various adaptations in production and consumption in order to adequately meet the emerging conditions and immediately restore the grid balance at the local, regional, national and international levels (ENTSOE 2010).

Europe closely maintains the power grid at a 50-Hz frequency. Frequencies over 50.1 Hz indicate an overload and require a disconnection of surplus production, while frequencies under 49.9 signify the opposite. The following paragraphs describe certain balancing measurements without focusing on technical details. This presentation of measurements demonstrates significant challenges for power grid governance, which requires adequate consideration during the complex planning for CIP.

The Power Production Side

A few decades ago, power production mainly involved large plants, such as coal-fired, nuclear or hydroelectric power plants. These types of generation units have a plannable capacity regardless of weather conditions. A stronger focus on renewable energies as part of electricity production has recently yielded wind parks and solar panels with a varied spectrum of capacities as well as an increased number of power producers. In particular, the output of these generation units depends on actual weather conditions. To maintain the balance of the power grid, automatic disconnection was required when the frequency exceeded 50.2 Hz. Studies have shown that, depending on the effect that is currently installed, this general requirement runs the risk of resulting in an over-adjustment (Boemer et al. 2011). Such an incorrect adjustment can prompt further instability in the grid and cascading consequences (Vaiman et

al. 2013). As a result, regulations now discourage an automatic disconnection of production units between 47.5 and 51.5 Hz (ENTSOE 2014; BMJV 2012). If the frequency falls below 47.5 Hz, production plants are disconnected to protect them from demolition (DVG 2000), which in turn requires a reduction in consumption to balance the frequency.

The Power Consumption Side

The reduction of electricity consumption – '*load shedding*', from the power grid perspective – constitutes a measurement to stabilise the frequency of the power grid. This applies when the frequency is low and no reserve can be activated or imported. The European Network of Transmission System Operators for Electricity (ENTSOE) has recommended a load shedding stepwise up to 50% of consumption between 49.0 and 48.0 Hz and an automatic shedding of heating pumps between 49.8 and 49.2 Hz for continental Europe (ENTSOE 2010). The members of the continental power grid collaborate with the members of the Nordic grid in balancing the grid through instabilities, which also stresses the significance of a European dimension of planning for CIP (Masera et al. 2006a). The Nordic power grid involves a part of Denmark in addition to Norway, Finland and Sweden (ENTSO 2006).

In Sweden, the planning for load shedding is twofold. The first part concerns a plan for *manual* disconnection of power consumption (MFK). All power grid providers are legally obligated to independently perform this MFK planning, which must enable each grid provider to disconnect at least 50% of the actual load. In order to protect critical infrastructure, this plan of disconnecting and reconnecting power consumption involves the results of the national planning approach *STYREL*, which Section 4.1.1 describes in detail. The second part addresses a plan for *automatic* disconnection of consumption (AFK). This AFK planning, which providers that are directly connected to the mentioned main power grid must perform, considers at least 30% of the actual effect for sites located in the southern part of Sweden, whereas the manual and the automatic disconnection scheme may only overlap by 5%. The latter AFK planning furthermore involves larger boilers and heating pumps, which is similar to continental Europe. (Svenska Kraftnät 2012)

Since private actors operate the majority of electricity production and supply, not just in Sweden, planning and co-ordination of measurements has become essential for CIP (Cedergren et al. 2015; Shore 2015). *STYREL* has been developed to facilitate the maintenance of critical societal functions during an under-frequency situation in Sweden. Alignment of the various demands, i.e. strategic objectives, of the socio-technical system of systems therefore requires careful consideration and governance.

2.4 Theoretical Framework for the Study

The previous sections have developed the conceptual framework for this study. Apart from a presentation of the Swedish *STYREL* case, theoretical concepts regarding systems and processes and their governance have established the scientific perspective of the case. This study focuses particularly on the role of strategic objectives for governance in complex planning environments. The Swedish planning for CIP constitutes the complex system which considers the core of critical infrastructure: the power supply. Since critical infrastructure disruptions can affect individuals, companies and public and private organisations on both national and international levels, planning and co-ordination of measurements has become essential to CIP (Shore 2015). Thereby, planning for CIP must balance private interests with those that are generally relevant for society. Such an equilibrium demands high standards for the executed activities with clear authorities and responsibilities and proper information sharing (Yusta et al. 2011). Hence, this study applies a holistic system view of the complex system of planning for CIP and employs the framework in Table 1 to thoroughly investigate the *STYREL* case.

Table 1: Conducting Aspects for Examining the Case

System	*Governance*	*Critical Infrastructure Protection*

▪ Components
  ○ Subsystems
  ○ Individuals
  ○ Technology
▪ Interrelations
  ○ Communication
  ○ Collaboration
  ○ Co-operation
▪ Conditions
▪ Constraints
▪ Adaption
	▪ Stakeholder
	▪ Rules & Policies
	  ○ Organisation
	  ○ Decision-making
	  ○ Controlling
	▪ Secrecy
	▪ Uncertainty
	▪ Ambiguity
	  ○ Goals
	  ○ Means
	▪ Environment
		▪ Interconnectedness
		▪ Quality
		▪ Society
		  ○ Resilience
		  ○ Risk events
		  ○ Surveillance
		▪ Globalisation
		▪ Risk Assessment
		  ○ Vulnerabilities
		  ○ Perceptions
		  ○ Preferences

Process	*Strategic Objectives*	*Power Supply*

▪ Object
▪ Resources
▪ Activities
▪ Actors
▪ Tools / Support
▪ Information flow
▪ Reference Model
	▪ Expectations
	▪ Experience
	▪ Future state
	▪ Alignment
	▪ Co-ordination
	▪ Perceptions
	▪ Communication
		▪ Importance
		▪ Interdependencies
		▪ Threats
		  ○ Weather
		  ○ Aging
		  ○ Demolition
		  ○ Cyber Attacks
		▪ Technology

3 Methodical Proceedings

Chapter 3 discusses epistemological, methodical and ethical considerations that support the research for this study. In addition, the chapter outlines the case study and briefly explains the proceedings of the corresponding papers. Sub-sections describe the methodological components for data collection and analysis in more detail as well as the treatment of limitations, which relates to the case and method selection.

3.1 Scientific Positioning of this Study

Since the time of Aristotle, there are three main approaches to extend the world of knowledge: deductive, inductive and abductive. The deductive option progresses from general to specific cases and consults existing theories and premises; it concludes logically through the use of mathematical principles. According to Aristotle, deduction builds an epistemological foundation to conclude rational and true insights (Kirchner, Michaëlis 1911, p. 96). In contrast, the second approach is based on empirical findings and observations. By way of induction, specific findings can be generalised to build upon the available body of knowledge (Welch et al. 2011). A third approach, namely abduction, can be useful for explaining observed divergences in facts. Thereby, a study can pose new hypotheses that facilitate the comprehension of sensations. Abduction applies either for drawing a conclusion from a major premise that is known to be true (Kirchner, Michaëlis 1911, p. 76) or for arguing about new hypothetic premises that remove the surprising character of the empirical perception (Hartshorne, Weiss 1934; Reichertz 2013). Peirce has summarised the approaches as follows (Hartshorne, Weiss 1934):

> *'Deduction proves that something **must be**; Induction shows that something actually **is operative**; Abduction merely suggests that something **may be**'.*

The attending problem concerning the validity of research findings is still subject to discussion throughout the research community. One tendency is the view of rationalism in science, which follows the basic attitude that cognition of reality is conducted through rationality and reasoning (Descartes, Hammacher 1996). The deductive approach is thereby used mainly as the appropriate mean. In addition, rationalists are sceptical towards empirical research and accordingly communicate doubts regarding the truth and relevance of empirical findings (Leibniz 1714). Another tendency is the approach of empirical knowledge. This approach uses gained experience as a strategy for conducting cognition (John Locke 1824) since acquiring knowledge *a priori* is considered impossible. Research that adheres to this

credo reflects general scepticism about the validity of scientific knowledge since it assumes that experience is empirical, and therefore only empirical experience can result in cognition (Hume 1998). In an attempt to combine these rather categorical approaches, Kant suggested that knowledge is based on empirical impressions, though cognition accrues by using the mind and reasoning on empirical impressions to structure perceptions (Kant 1990).

In summary, a key question is the extent to which knowledge can be considered universal and true. According to Popper, who has distinctly influenced the discussion regarding research and theory, definitive knowledge is impossible (Popper 1935). He has opined that the only way to perform research is to falsify statements against theory, which implies that one can demonstrate that an idea is *not* true but never that it *is* true. Even Gettier has queried the quality of reasoning by arguing that a justified true belief can be true, per accident, even though someone's reason for the belief is false (Gettier 1963). However, estimating the reason's quality – which underlies an individual belief that a claim is true – requires general valid criteria, and these are still absent. It is therefore claimed that the term 'knowledge' is indefinite (Welding 2016), similarly to the concept of theory on which to base that scientific knowledge (Bichler et al. 2016b).

Hence, this thesis applies the term 'knowledge' with an understanding of its limitations. Since this study impartially pursues solutions that best suit the demands (Niemann 2008), it aims to provide proper evidence for the reasoning to convince the well-disposed reader. In consequence, during the inquiry of the Swedish *STYREL* case, which represents a complex system for emergency response planning for CIP in cases of power shortages that processes sensitive information and relies on formal, informal and technical structures, the investigation adopts a rather holistic attitude to move beyond the distinction between constructivism and (neo-)positivism (Mingers et al. 2013). The complexity of the case, the heterogeneity of the related information systems and the variety of actors hamper a formal modelling. Moreover, the particular perceptions of the interviewees cannot completely explain the behaviour of the whole system. Nevertheless, the empirical inquiry can reveal important insights to represent and analyse the existing complex system and its governance, and furthermore to inform the suggestion and design of *new* systems, processes, theories or technological rules. Thereby, this study gravitates towards a realist perspective in design-oriented information systems research, but it strives heavily to learn from commonalities and overlaps rather than from differences in research paradigms.

3.2 Research Design

In accordance with the epistemological and ethical considerations that this chapter provides, the sub-sections describe the methodical proceedings of the study. This outline of performed actions and employed methods can enable the reader to comprehend the presented results and associated conclusions. In addition, Paper IV provides further theoretical background for epistemological and methodical approaches in information systems research.

3.2.1 Material and Method

The methodical approach of a case study constituted the main research strategy of this study. This choice allowed this study to investigate a complex phenomenon while maintaining a holistic and realistic perspective (e.g. Flyvbjerg 2011; Yin 2014). According to Yin, a case study is a proper method if a study seeks to understand a real-world problem in depth and within its context when the borders between problem and context may be fluid (2014 p. 16). This study selected the Swedish *STYREL* case because it constitutes a real-world phenomenon with significant complexity.

Selection of the Swedish case narrowed the research field of complex planning environments to the problem area of CIP and its backbone, namely the emergency power supply. Nevertheless, since this national case is still complex and can be approached from different angles, this study focuses particularly on the involved strategic objectives. Although a single case study may be unable to provide all-encompassing answers to any type of question, it can reveal valuable insight into real-world phenomena. The Swedish emergency response planning for cases of power shortages seems to be unique in scientific literature, which limited alternative method selections. In contrast, the unique experiences from this complex planning, which Sweden has implemented, can also be of interest beyond the Swedish context for similarly complex planning situations. However, in view of the extent and complexity of such planning approaches, a timely effort for a thorough investigation could not be underestimated. These conditions motivated an adequate limitation of the study's focus. Hence, of the many variables of interest in the Swedish case, this study specifically concerns challenges that confront governance in the context of such complex planning environments.

Apart from the selection of a particular lens of investigation, the use of multiple sources of evidence can arguably benefit the overall quality of case study research (Flyvbjerg 2011; Yin 2014, p. 119). Although this study mainly used documentations and interviews, it also incorporated observations that enrich the evidence. Archival records could not be included due to

information security concerns. Moreover, this summary and the four articles, which together comprise the thesis, are parts of the case study. They apply several method components to collect and analyse evidence for a segment of interest to address the research questions in detail (see Section 1.3). Table 2 summarises the material, approaches and method components in each component of the thesis.

Table 2: Research Approaches, Material and Methods

Part of the Thesis	*Main Approach*	*Material*	*Method Components*
Summary	Case Study	▪ Articles included	▪ Content Analysis
Paper I	Multidisciplinary Inquiry	▪ Primary literature regarding the case	▪ Content Analysis
Paper II	Design-oriented	▪ Primary literature regarding the case ▪ Expert interviews	▪ Content Analysis ▪ Modelling ▪ Model evaluation
Paper III	Empirical	▪ Primary literature regarding the case ▪ Expert interviews	▪ Content Analysis ▪ Observation
Paper IV	Theoretical	▪ Theory associated with the research field and research paradigms	▪ Literature review ▪ Modelling ▪ Model evaluation

Each paper provides a separate method description which details each applied approach. The following section briefly describes the methodological instruments for this study.

3.2.2 Method Components for Data Collection and Analysis

In view of the complexity of the *STYREL* case, this study has hitherto analysed parts of the human activity system and information processed (Avison, Taylor 1997). The examination employed several methods and components for data collection and analysis and the design of conceptual models. Apart from conducting the literature review on the research field and problem area, this study mainly examined primary literature related to the case and interviews with involved experts. It additionally entailed the development of models, which are rooted in the results of the primary literature content analysis, and their evaluation, e.g. during interviews with experts involved in the Swedish case.

The Document Study. This part examined the primary literature on the case. This included official documentations, national laws and legal regulations, reports of local evaluations, meeting protocols, user guidelines and trainings. The analysis used various parameters related to the theoretical framework in Table 1 during several iterations to identify relevant information in the documents and understand particular aspects of the problem situation. The interview transcriptions were subsequently subject to in-depth content analysis comparable to this summary's analysis of the content of the articles.

The Interview Study. The research for this part involved consultation with 20 experts from power grid providers as well as responsible individuals at municipalities of two geographically distinguished counties and their CABs. The size and structure variation in the regions allowed for a broad spectrum of local experiences, requirements and constraints, which supported a thick description of the situation. Semi-structured face-to-face interviews were conducted, with the exception of one that was conducted via telephone. A survey guide with open-ended questions was employed to ensure a similar structure in each interview and allow participants to report on individual experiences and perceptions. Follow-up questions were posed to achieve more clarity and richness of detail. The interviews lasted one hour on average and were recorded and transcribed. The proceedings further entailed anonymising and aggregating the material and results to protect sensible information related to topics such as participants or critical infrastructure. Moreover, when participants wanted to discuss issues without being recorded, this was always permitted. In such circumstances, the researcher's observations completed the data collection. Content analysis followed the process in the document study as described above. In addition, recordings were replayed in order to gain a deeper understanding of nuances in meanings and verbal expressions.

Modelling and Evaluation. Models are widely used to facilitate a common understanding of complex matters, and they are accordingly useful in the context of complex planning environments. This study developed three models that support the communication process towards a shared understanding of the complex implications of planning environments, such as the Swedish case for CIP, for both governance and research.

Mapping, reduction and pragmatism are essential characteristics of a model. A modeller maps an original, such as the complex case *STYREL*, with a specific intention; certain, subjective abstraction thus occurs within the modeller's individual-cognitive model. However, a goal-oriented, objective abstraction decreases the complexity of the original. To be meaningful for a future user, such a model must address the perspective of an intended target

audience and therefore consider the relevant purpose as well as chronological and expedient integration. (Stachowiak 1973, pp. 131–133)

Since these characteristics of a model require an evaluation of its features, scholars have suggested various approaches to evaluate models in information systems research (Fettke, Loos 2003; Hevner et al. 2004). Paper II applies an evaluation by experts, and Paper IV demonstrates an application of the model. The evaluation in Paper II entailed asking experts who perform the *STYREL* planning about their perceptions of this model. The comments informed improvements to the model, which in turn enhanced communication about the nexus of the case during further interviews. Paper IV illustrates how this model arranges theories and methods that surround the complex planning case.

3.2.3 Treatment of Limitations

This study is subject to certain limitations because, as mentioned, a single case study approach limits the generalisability of results. However, the primary intention of this study is to extend the base of knowledge rather than to provide a generic answer to the topic (Welch et al. 2011). Thereby, this study represents variety in real-world phenomena and advances the level of detail in knowledge, which benefits further developments in both research and praxis regarding complex planning environments.

Since planning in the context of CIP addresses sensible data and weaknesses in the system, access to data was restricted. This caused further obstacles in the document and interview study. The data collection consequently relied predominantly on publicly available Swedish literature and personal interviews. Confidential information acquired through data collection has been handled with care. Sensitive information was omitted, condensed or anonymised during analysis with respect to relevance for the study's focus.

Due to time constraints, not all key stakeholders could be interviewed, which posed another limitation to the empirical side of the study. To address this, participants were gradually selected to appropriately represent diversity in complex environments that interrelates with the various components, relations and conditions.

Furthermore, the data analysis applied a hermeneutic approach to primary literature and interviews. This proceeding imparted a deeper understanding of the complex structures in the Swedish case and the strategic objectives behind it. This necessitated deliberate, reflected subjectivity of the analyst to interpret data and results that could provide new insights (Breuer et al. 2002; Reichertz 2015). This process of data analysis and interpretation also took the

interview situation into account, as the researcher's observations of non-verbal communication, if any, may have influenced the interaction with the material. Such interaction informed a thick description of the case material.

Moreover, the investigation needed to meet limitations in time and structure to fulfil the institutional requirements for a cumulative dissertation in a predetermined period. Therefore, the acquired data was continuously analysed under the lens of the stated research questions to examine different aspects of the presented problem. The aim was to complete this thesis with separate scientific publications that all thematically interrelate to the case study. Apart from this, considerations regarding ethics and confidentiality might have restricted the evidence. Papers I-IV indicate such limitations, if any, in greater detail.

3.3 Ethical Considerations

Ethics in research considers a large field of tensions through attention to many issues, such as the research process, the researcher and the research subject. Relationships between individuals as well as their actions and subjectivities are particularly important. Hence, research that involves humans – as subjects or conductors of studies or as consumers of results – must incorporate several questions concerning responsibility, adequate objectivity and independence. Such questions can involve both legal questions of privacy and philosophical questions of applied, activity-oriented ethics. In addition, political and theoretical questions of positioning research and researchers in certain societal and methodical circumstances can provoke further considerations that include a researcher's (self-) reflexivity (Unger 2016). All of these questions address the mentioned issues with regard to the entire research process and the relation between the researcher and the subject of research.

Ethical considerations during research therefore strongly connect to the research persona who prepares and performs the process. Although relations between a researcher and a research subject are mostly in the centre of discussions, each methodical component of a research process can have consequences for researchers as well as research subjects. Kant has suggested the following for ethical behaviour: '*Morally good conduct is based on practical reason*' (1788, pp. 54–56). He argued that an individual must behave in a morally good way to obtain credibility in a society or group, and therefore only *morally good conduct* could be a reasonable behaviour. However, even though reasonability renders morally good conduct advisable, it remains to discuss how individual experiences and learned patterns may influence free will and thereby impact such practical reasoning (Schultze-Kraft et al. 2016).

Morally good behaviour of a researcher necessitates maximum transparency, as this may affect many aspects of a research process (see e.g. APA 2010; Breuer 1996, pp. 36–40; Gustafsson et al. 2011; Wissenschaftsrat 2015). Table 3 indicates these aspects and how this study addresses them.

Table 3: Ethical Aspects addressed during the Thesis.

Aspect	*Description*	*Application*
Veridicality	Establish openness by presenting methods, materials, results and conclusions. Appropriate efforts reveal integrity of the research that supports credibility.	This thesis, i.e. the summary and the embedded papers, details the methods for data collection and analysis as well as the results and conclusions.
Disclosure of interests	Distinctly present interests to encourage adequate interpretation of research. Emphasise interests that relate to particular principals or which may pose conflicts.	It is gratefully acknowledged that the Swedish Energy Agency financially supported the research. No conflicting interests were disclosed that related the support to predetermined results.
Replicability	Explain the performed actions and applied methods and theories. Readers should be in a position to understand and follow the research process and results.	The thesis seeks to offer adequate information about actions, methods and background as well as interpretations.
Application of good standards	Involve reflection on common norms and expectations regarding the research process and proper method selection that is inclusive of the treatment of informants.	Chapter 3 of this summary addresses these particular reflections. Other sections and the papers also discuss this issue to varying extents.
Publication of results	Reflect on the researcher's self-censorship, which may occur during topic selection and the determination of the completeness of this study. Effects of principal's interests may also be considered.	Two papers have been published, and two are under review by journals. Material and results concern the examined topic. Section 5.4 notes remaining issues for further research.

Since planning for CIP processes sensitive information on vulnerabilities and particular circumstances, this study respects information security and privacy concerns, as this chapter has indicated. These deliberations of epistemological, methodical and ethical issues establish the philosophical and methodical frame of the inquiry. The next chapter presents the results of the examination.

4 Results

Chapter 4 presents the results of this study. The exposition of the STYREL case commences the chapter. Thereafter, an overview indicates how the summary and articles relate to the research questions and which main findings they provide accordingly. Moreover, a short presentation of each paper demonstrates its particular importance for approaching the research problem. A synthesis connects the results and provides a conceptual framework that generates a context for a constructive dialogue about strategic objectives in complex systems.

4.1 Overview of the Case Study

The following sub-sections concisely present the case and the results of the investigation. The first section outlines the *STYREL* process that the complex planning environment for CIP in Sweden executes for cases of power shortages. Then, an overview presents the results in aggregate form.

4.1.1 The Case of *STYREL*

This study investigates the complex system that surrounds and executes the planning process *STYREL*, which is a Swedish planning approach to facilitate swift response during power shortages through anticipated decision-making. The acronym *STYREL* translates from Swedish to English as 'steering power to prioritised consumers'.

Imbalances of power production and consumption require permanent control activities to keep the power grid in a stable state, as explained in 2.3.2. This balancing can thereby lead to power outages for some consumers. Depending on certain circumstances, such as weather conditions or accidents, a swift response to such problems is necessary to protect society from negative consequences. The Swedish approach preemptively identifies critical power consumers and their importance for society. For this purpose, it uses an eight-point scale, which Table 4 presents, to classify these key consumers in terms of importance (MSB 2010, p. 10). Apart from this scale, no further decision aid is available.

The Swedish government entrusted the Swedish Energy Agency (SEA) with establishing emergency response to ensure the power supply. The *STYREL* approach began development in 2004, and the first national execution in 2010/2011 completed its implementation. Since the planning approach stipulates new iterations at four-year intervals, the second execution of the process was performed 2014/2015 and was intended to run as presented below (SEA 2014). Table 5 provides further details about the involved actors.

First, at the national level, four national authorities that are charged with energy issues and crisis prevention (see I to IV in Table 5) commence the planning process. The SEA (II), commissioned by the mentioned authorities with overall responsibility for the process execution, informs other national agencies (V) which operate critical infrastructure as well as all county administrative boards (CABs; VI). The national agencies are requested to invent critical infrastructures for which they will each be responsible. This inventory identifies power consumers which maintain this infrastructure and prioritises their importance for society according to the scale in Table 4. The national agencies then deliver the results of their inventory to each CAB where the respective infrastructure is physically located.

Table 4: Classification Scheme of Critical Infrastrucure (MSB 2010, p. 10)

Class	*Description*
1	Power consumers that have a large impact on life and health in a short time frame (hours)
2	Power consumers that have a large impact on vital societal functions in a short time frame (hours)
3	Power consumers that have a large impact on life and health in a longer time frame (days)
4	Power consumers that have a large impact on vital societal functions in a longer time frame (days)
5	Power consumers that represent large economic values
6	Power consumers with major importance for the environment
7	Power consumers with importance for societal and cultural values
8	All other power consumers

Second, the CABs initiate the execution of the planning at the regional level and provide information on the proceedings to their belonging municipalities. In addition, each CAB further divides the inventory of the national agencies and prepares a particular selection for each municipality (VII).

Third, at the local level, municipalities are encouraged to invent their infrastructure to identify power consumers that are vital for the local society. Moreover, responsible individuals at municipalities prioritise these key consumers by applying the mentioned scale. With respect to the limitations to controlling electrical power, municipalities must further observe technical feasibility. Therefore, local grid providers (VIII) provide information on the relation of the power consumers to controllable power lines. Thereby, various consumers — each with its individual prioritisation class — aggregate to different power lines. A spreadsheet that performs an additive aggregation

constitutes the information technology support for this aggregation. To eliminate possible flaws due to the aggregation, municipalities are encouraged to manually assess the ranking of the resulting power lines. Upon completion of this assessment, the municipalities forward the resulting list, which contains the ranking of local power lines, as a suggestion to the CAB responsible for the region.

Following the ranking list back to the regional level, the respectively responsible CAB then prepares a compiled ranking list, which involves all lists from their belonging municipalities, by using another spreadsheet that automatically applies another additive aggregation. Each CAB shall specifically consider power lines that cross local and regional boarders — in co-operation with municipalities and neighboring CABs — so that the resulting compilation is adequately attentive to the initial classification of key consumers. Each CAB then forwards the completed compilation to the Swedish National Power Grid Provider (SvK; IV) and the respective parts of the ranking list to the interrelated regional and local power grid providers.

Table 5: Actors involved in the Planning Approach - *STYREL*

Nº	*Actor*	*Information*
I	Swedish Civil Contingencies Agency	Charged with national prevention, contingency and crisis management
II	Swedish Energy Agency (SEA)	Charged with issues regarding energy and its supply to consumers
III	Swedish Energy Market Inspectorate (EI)	Charged with controlling of the Swedish energy market, pricing and policies
IV	Swedish National Grid Provider (SvK)	Charged with maintenance of the national power grid and power supply
V	National agencies	Up to 337 agencies responsible for various tasks affecting the national society
VI	County Administrative Board (CAB)	21 counties representing the government at the regional level
VII	Municipalities	291 municipalities representing society and acting locally
VIII	Grid Providers	Around 160 operators responsible for grid maintenance and power supply at the regional and local levels

At the next level of planning, which is not included in the *STYREL* core process, all power grid providers are legally obligated to use these allocated ranking lists to plan their response during cases of power shortages. This allows for maximum adherence to the ranking list during an emergency.

4.1.2 Synopsis of Results

This licentiate thesis consists of four papers and a summary. The summary primarily consolidates the study, while the papers address different facets of the research problem. Table 6 presents insights from the theoretical investigation and methodical proceedings. Table 7 provides a summary of the results and demonstrates their relation to the research questions and parts of this study. This synopsis condenses the most significant results, while the sections below elaborate on the papers and their particular contributions.

Table 6: Theoretical and Methodical Results of this Study

	Insights from the theoretical inquiry in accordance with strategic objectives in complex planning environments
Paper I	Characterises *STYREL* as a complex system of actors with interests as key that dominates the networks and reveals potential conflicts of the various interests for adequate decision-making
Paper III	Assigns the multi-level planning concept to national emergency response planning for CIP and shows that strategic objectives emerge at each level of planning and decision-making depending on the granularity of the investigated hierarchy
Summary	Distinguishes four classification parameters of strategic objectives: (1) Manifestation: implicit or explicit, (2) Sequence: intermediate or advanced, (3) Logic: identical, compatible or antinomic and (4) Side effect: beneficial, neutral or conflicting
	Results from the methodical proceeding
Paper I	Uses a multidisciplinary inquiry to analyse documentations of the national case and findings from previous research and applies four perspectives on the *STYREL* case: (1) Governance, (2) Participation, (3) Risk Analysis and (4) Decision-Making
Paper II	Models the complex system that surrounds and executes the *STYREL* process by adapting the concept of the Soft Systems Methodology to design-oriented information systems research
Paper III	Applies the concepts of multi-level planning and uncertainty in planning and decision-making to the Swedish case to assess how the *STYREL* process is integrated into national emergency response planning and which sources of uncertainty interrelate with lack of knowledge in multi-level planning
Paper IV	Designs a multi-perspective kaleidoscope for complex and multi-/interdisciplinary research problems and demonstrates the usability by applying the conditions of the given case

Table 7: Overview of the Results and their Contribution to the Research Questions

RQ 1: Which conditions represent the complex system of response planning for power shortages and its environment of CIP in accordance with STYREL in Sweden?	
Paper I	Discusses (1) public and private actors connected by the *STYREL* process for collaborative response planning, (2) stakeholders affected but not involved in the process, (3) system governance, supporting analysis, decisions, quality / process management
Paper II	Displays a conceptual system model of the complex planning environment with actors as system components, including their concerns, roles and interrelations alongside the *STYREL* process
Paper III	Reports interrelations and conditions, provided by the different planning levels from strategic planning to application of the resulting plan, and the integration of *STYREL* into Swedish CIP
RQ 2: Which sources of uncertainty and strategic objectives emerge from multi-level planning in general and from the complex system of emergency response planning for CIP and the interrelated STYREL process in Sweden in particular?	
Paper I	Indicates decisions under risk related to sources of uncertainty as (1) the duration of power shortage and (2) the value loss of a power shortage given a known duration; reveals involved and affected stakeholder groups as sources of strategic objectives
Paper III	Specifies sources of uncertainty with regard to lack of knowledge as (1) the complex planning (reference) process, (2) the decision-making process and (3) the direction and guidance; shows that strategic objectives emerge at all levels of the multi-level planning and interrelate in a hierarchical order
RQ 3: How do the implications of these systemic conditions and strategic objectives affect governance of the complex planning environment for CIP in Sweden?	
Paper I	Proposes implications in need of clarification: (1) governance and participation, (2) decision support, (3) process structure and leadership and (4) scope and terms of process and system
Paper II	Suggests actions to improve *STYREL* regarding (1) the usage of the resulting plan, (2) better communication, (3) improvement of feedback loops and (4) adapted guidelines and decision aid
Paper III	Yields parameters to address by system governance regarding (1) the response planning (reference) process, (2) the identification and prioritisation of critical infrastructure and (3) the direction and guidance alongside (1) & (2), and (4) further factors.

Summary	Raises awareness of three main challenges for governance that strategic objectives provide, which emerge from the systemic conditions of complex planning environments: **(1) *Opportunities***: find and promote compatible strategic objectives that rely on means with beneficial side effects **(2) *Indefinites***: monitor and assess strategic objectives to dissolve identical objectives and to identify future *Opportunities* or *Risks* **(3) *Risks***: find and mitigate antinomic strategic objectives and compatible ones that apply means with conflicting side effects

4.2 Presentation of Individual Results

While the previous section has briefly demonstrated the results, the following sub-sections explain the individual papers in greater detail and indicate each article's contribution to the research in this study.

4.2.1 Paper I

The article entitled '*Collaboration and Decision-making in Response Planning for Power Shortages: The Swedish Policy*' critically reviews the Swedish *STYREL* case as it is described in regulations, guidelines and policy documents. Theoretical concepts from literature constitute the framework for the investigation and analysis of collaboration and decision-making in the presented context. The article employs a multidisciplinary view to approach the Swedish planning for CIP against power shortages. The theoretical inquiry reveals interests and objectives to be key for actor networks and their collaboration, decision-making and stakeholder participation, which characterises the system that executes *STYREL* as complex in view of the underdeveloped structures and unpredictable consequences of the process. To address three main aspects — the stakeholders, the conditions and constraints, and the risks and benefits that interrelate with the *STYREL* process — this study employs four perspectives:

(1) A governance perspective addressing network and controlling issues
(2) A participation perspective examining stakeholder involvement
(3) A risk analysis perspective investigating risks and benefits and considering uncertainty in the planning
(4) A decision-making perspective analysing the information processing and decision support

Apart from the actors identified and described in Table 5, the paper reveals stakeholders who may be affected by the planning process but are not

included. This stakeholder group consists of actors from the Swedish crisis and emergency management, non-governmental organisations, small private operators of critical infrastructure and the civic society in general. Furthermore, the paper discusses co-operation and collaboration between the actors in the distributed complex planning environment. This discussion highlights the absence of any deliberate feedback in the planning approach as problematic for both the commitment of involved actors and the evaluation of the process. Such a lack of feedback also affects the system conditions within this complex planning environment, which may adapt to this absent feedback and in turn impact the quality of decision-making. The partial study determines that the information processing in the distributed network is a particularly challenging condition. This finding involves several aspects, such as strategic objectives and their communication via user guidelines, information collection and decision-making through the planning process, and considerations regarding information security issues.

Furthermore, the review in the article raises the question of the extent to which decision-making during the planning approach relates to concepts of risk and uncertainty. From the classification scheme used as a decision aid (see Table 4), the inquiry identifies two sources of uncertainty: the duration of the power shortage and the value loss of the power shortage given a known duration.

This study contributes to the development of strategic planning in similar contexts, which would involve human causes and societal consequences of such planning efforts. It argues that *STYREL* cannot yet be considered to be fully developed, and it identifies three areas that governance must address: (1) scope and terms of the process, (2) a (better) quality management and (3) a more sophisticated decision aid. By providing suggestions for improvement, the paper supports the future development of *STYREL* and similar cases.

4.2.2 Paper II

The article entitled '*Applying Systems Thinking onto Emergency Response Planning: Using Soft Systems Methodology to Structure a National Act in Sweden*' examines the case from a soft operations research perspective. It adapts the Soft Systems Methodology to design-oriented information systems research. This partial study develops a conceptual system model that is based on analysis of primary literature on the case. This model consists of three sub-models: (1) the Rich Picture, which Figure 2 presents, (2) a core root definition of a generic system model and (3) an action model. Ten experts at municipalities and local power grid providers that are involved in the *STYREL* planning have evaluated this conceptual system model.

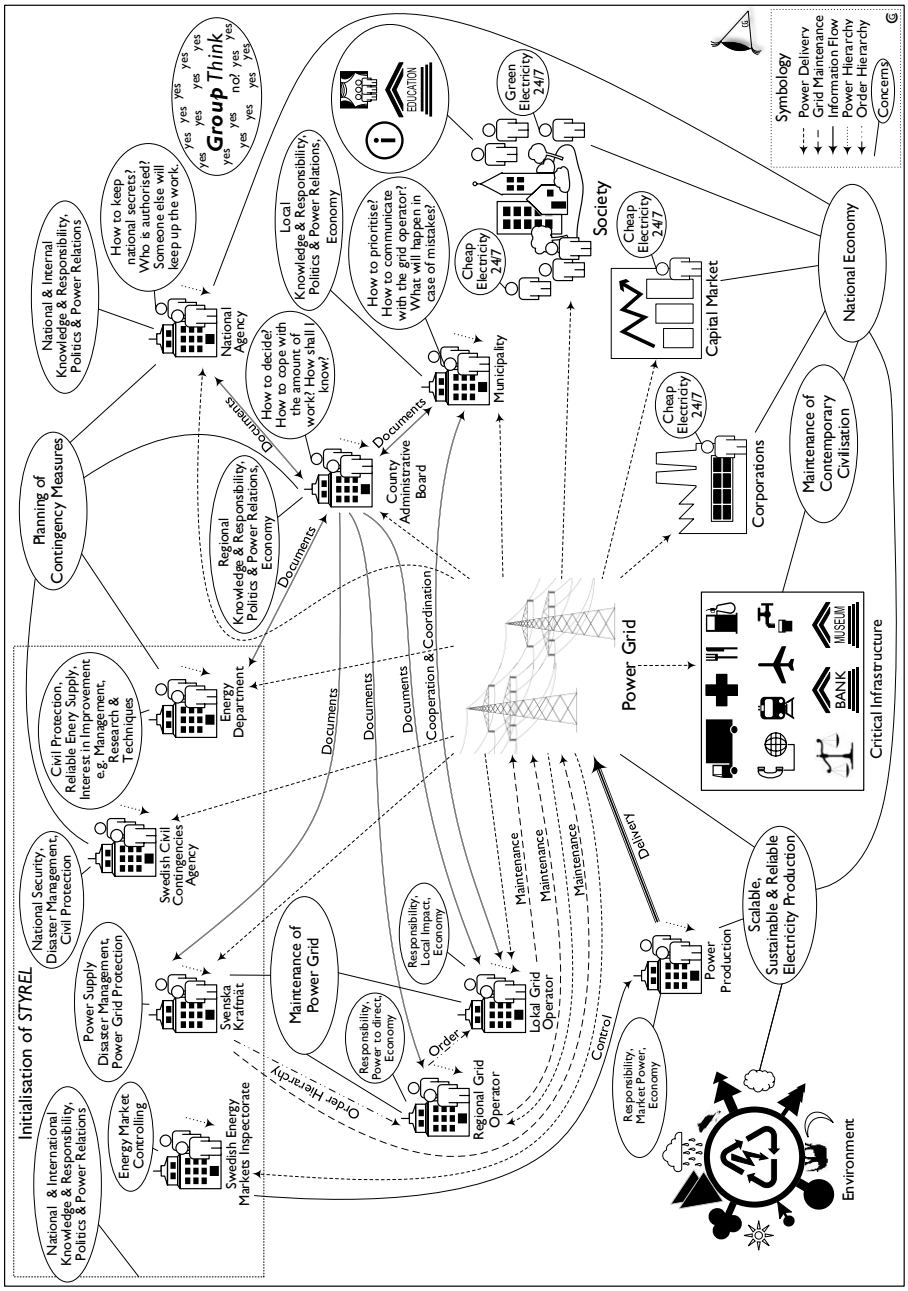

Figure 2: Rich Picture of the Complex System Surrounding and Executing *STYREL*

The conceptual system model emphasises components, interrelations and surrounding conditions in the complex planning environment of *STYREL*. The

Rich Picture first visualises the problem situation, including actors, power relations and focus areas. Based on this segment of the real-world phenomenon, the core root definition enhances the understanding of involved actors and their roles in the complex *STYREL* planning system. This generic system model further indicates preconditions and constraints, such as the prevailing *Weltanschauung*, legal regulations and technical limitations in the particular context. Advancing from this generic model, additional abstraction from the underlying case yields an action model that contains relevant actions in the context of response planning for power shortages. This action model indicates relations between actions and helps to identify interactions and adequate controlling activities. The experts appreciated the visualisation of the system and the concretised structure, and they expressed further concerns with regard to the conditions and requirements of *STYREL*.

Paper II evidences that short-term management, i.e. applying governance in practice, and execution of emergency response planning are complex endeavours that require target-group-oriented communication and governance. The interviewees noted further changes and actions for the particular context of *STYREL*. The results imply that the distributed environment of *STYREL* challenges governance with regard to alignment and achievement of strategic objectives and continued motivation of responsible persons. This study thereby offers an informal basis for the development of adequate information paths and assists with visualising the complexity of emergency response planning for CIP for power shortages in Sweden. The conceptual model additionally facilitates a future dialogue on information paths and work flows, responsibilities, governance and collective learning.

4.2.3 Paper III

The article entitled '*Sources of Uncertainty in Swedish Response Planning*' focuses on uncertainty in planning and decision-making. It investigates sources of uncertainty that are associated with a lack of knowledge in the context of complex planning environments. In particular, Paper III presents theoretical concepts regarding multi-level planning and national emergency response planning as well as uncertainty in planning and decision-making for CIP. The derived framework for theoretical analysis contains several parameters and a model that represent characteristics of multi-level national emergency planning. This study uses this framework for a comprehensive analysis of *STYREL*. First, the analysis examines the primary literature on the case and reveals three sources of uncertainty: (1) the complex planning process, (2) the decision-making process and (3) the direction and guidance alongside (1) and (2).

Second, the analytical framework guided interviews with experts who are entrusted with the planning at municipalities and CABs. The results of these interviews characterised the identified sources of uncertainty in more detail.

The contribution of Paper III is twofold. First, the results from the review of scientific literature present interdependencies between different levels in multi-level planning, such as (A) strategic, tactic and operational planning, (B) the execution of planning with decision-making and (C) the usage of the plan, and it applies these levels to national emergency response planning. As Figure 3 indicates, the document analysis regarding the case then concretises this multi-level planning concept (MLP) for *STYREL* and its context of national emergency response planning (NERP) for power shortages and blackouts.

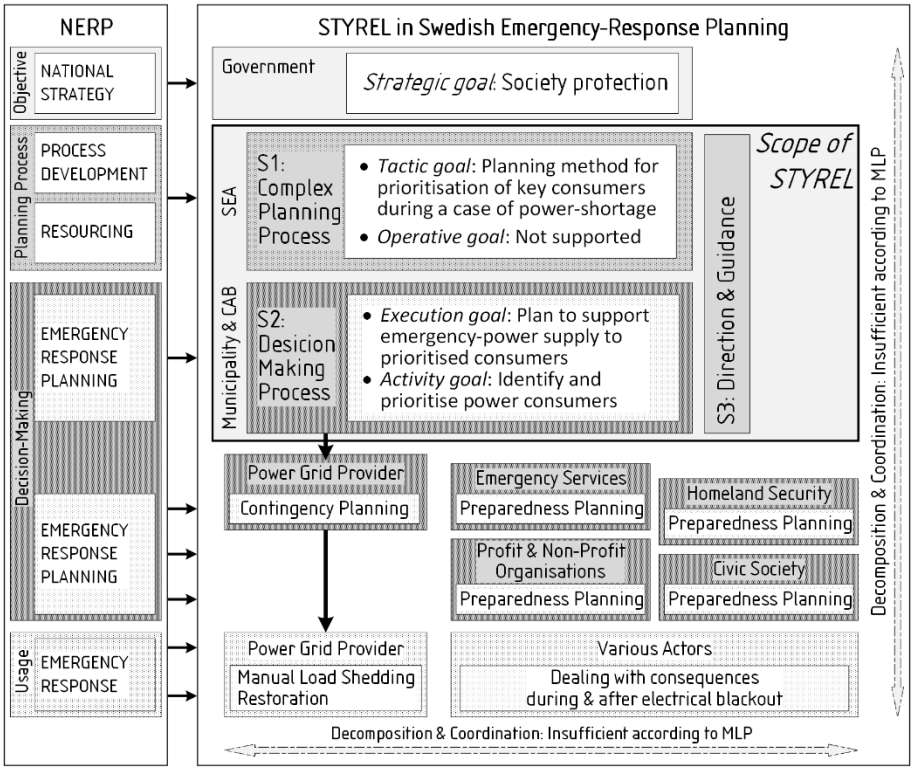

Figure 3: Sources of Uncertainty according to the Multi-level Planning *STYREL*

Paper III specifically reveals three sources of uncertainty that correlate with lacks of knowledge in complex planning environments, S1-3 in Figure 3.

S1: The complex planning process includes the tactical and operative planning of the execution process, which in *STYREL* addresses the reference process model (development) with resource planning and allocation.

S2: The decision-making process relates to the execution of the planning, which in *STYREL* includes the identification and prioritisation of critical infrastructure that depends on the power supply.

S3: The direction and guidance appear alongside *S1* and *S2* to align objectives, goals and means throughout the complex planning environment, which in *STYREL* relates to local, regional and national governance.

Further parameters, which the interviews with decision-makers have refined, explicitly specify these sources of uncertainty in Paper III. Thereby, the article highlights particularly important components and the hierarchical structure of national planning for CIP in response to power shortages. In addition, this partial study discusses strategic objectives in correlation with the single levels of planning as identified during the steps of the analysis.

Second, the empirical results of this study extend the three sources of uncertainty in multi-level planning with more complex interrelations and components. Participant-derived insights emphasise that governance efforts need to focus on many interrelations, such as those between the uncertainties in multi-level planning, the characteristics of a decision-maker and the planning environment that surround such a decision. In particular, the decision-makers' experiences associated with planning, execution and governance expose issues that are interconnected with these sources of uncertainty, such as information technology support, decision aid and collective learning.

4.2.4 Paper IV

The article entitled '*Research in Complex Planning Situations: Dimensions and Challenges from Swedish Response Planning*' used the research process of design-oriented information systems research (Österle et al. 2011) to compose a multi-perspective kaleidoscope for complex and interdisciplinary research. Applying this kaleidoscope allows researchers to design an individual research strategy that is adequately adapted to a complex research problem. The article evaluates the multi-perspective kaleidoscope by applying it to the research problem of complex planning environments as depicted by the *STYREL* case.

Although the article applies a rather theoretical meta-perspective, it also indicates components, interrelations and conditions which can have an impact on a research strategy design in a particular context. For instance, different research fields can approach systems and their properties by applying various theoretical concepts. Moreover, interrelations between research fields can lead to overlapping research areas that may employ similar terms with different meanings. Moreover, research projects on complex

planning environments, such as the *STYREL* case, face specific conditions with regard to time, financing and capacity, for instance. Such conditions can impact the scope and comprehensiveness of the particular research project.

Paper IV particularly focuses on how to integrate separate research fields and sub-areas, and it thereby contributes elaborately to method development. The presented kaleidoscope enables scholars from different disciplines to develop a joint interdisciplinary research strategy for approaching a complex problem from multiple angles while still retaining a holistic perspective. An adapted interdisciplinary research design can more comprehensively address various facets of a complex research problem. In addition, this kaleidoscope facilitates communication about the selection process of a research methodology within a project group, among the research community or to third parties. Figure 4 illustrates the conceptual model of the multi-perspective kaleidoscope.

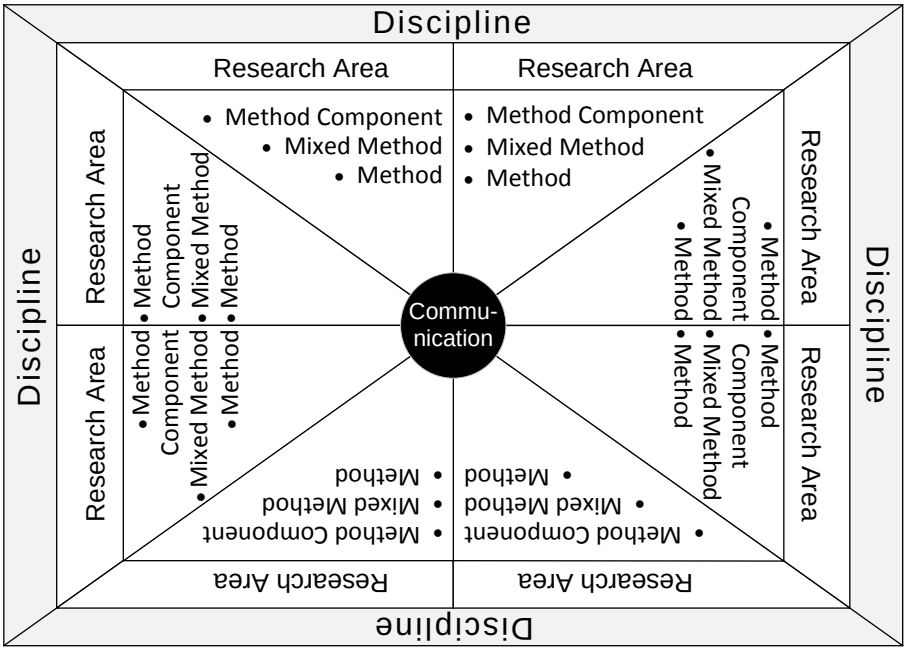

Figure 4: Conceptual Model of the Multi-perspective Kaleidoscope

The previous sections have detailed the various facets that the papers in this thesis address and have signified their contributions to this study and the research questions. The following section conflates the results, which were obtained through the summary and the single papers, and composes a conceptual framework for approaching strategic objectives with respect to their effect on governance of complex planning environments.

4.3 Composition of the Context for a Constructive Dialogue

The discussion within this thesis indicates how strategic objectives challenge governance of complex planning environments. The previous sections have introduced the planning for CIP as a complex system which consists of many sub-systems that maintain interrelations within a distributed environment. Moreover, the particular focus on the case of power shortages adds technical conditions provided by the power grid which further constrain the field of actions for governance. Given these circumstances, it seems likely that goal conflicts will arise and force governance into action. Such goal conflicts, which emerge from differing strategic objectives, can be stipulated by, for example, stakeholder needs, economic interests, technical requirements or political considerations. Hence, a thorough investigation and balancing of these strategic objectives is imperative to adapt governance efforts.

The results of this case study have informed the composition of the context for a constructive dialogue, which is delineated below. This conceptual context consists of three main parts: (1) the properties of strategic objectives, (2) the systemic conditions of complex planning environments and (3) the challenges that combinations of strategic objectives pose for governance.

First, as Section 2.2.3 has detailed, properties of strategic objectives constitute classification parameters for investigating strategic objectives and their interrelationships. The conceptual framework therefore involves the following properties and ***classification parameters***:

- *Manifestation*: implicit or explicit
- *Sequence*: intermediate or advanced
- *Logic*: identical, compatible or antinomic
- *Side effect*: beneficial, neutral or conflicting

Second, in accordance with the system perspective presented in Section 2.2.1, the system components, their interconnections and their environment provide relevant parameters to the conceptual framework. As Section 2.2.2 has explained, stakeholders are particularly important for governance in complex planning environments. The findings presented in the articles and discussed above reveal that the results of a planning for CIP can involve or affect stakeholders, or even both. Moreover, this thesis demonstrates that interrelations between these system components and the information flow alongside them are substantial for both the alignment of strategic objectives and the co-ordination of activities towards them. In addition, stakeholders and further system components are surrounded by their particular environments, which at the same time contribute to a larger system environment. This larger environment in turn exhibits notably fluid borders

in the context of CIP, as Section 2.3 and the results discussed above have indicated. These particular conditions can restrict the range of strategic objectives, so the framework includes the following systemic parameters:

- *Component*: technology and stakeholders (individuals and groups)
- *Interrelation*: between components including the information flows
- *Environment*: surrounding components and the system

Third, the strategic objectives – which derive from the systemic parameters in the complex planning environment for CIP – encounter the stated classification parameters. Thereby, combinations of strategic objectives can emerge that challenge governance in complex planning environments. Such a combination of strategic objectives can provide one of the following ***challenges***:

- *Opportunities*: explicit, intermediate or advanced, compatible strategic objectives that rely on means with beneficial side effects
- *Indefinites*: implicit or explicit, intermediate or advanced, identical or compatible strategic objectives that use means with neutral side effects
- *Risks*: explicit, advanced antinomic or advanced compatible strategic objectives that apply means with conflicting side effects

These challenges emphasise the importance of monitoring and regularly assessing the strategic objectives involved in complex environments in order to enable governance to adequately identify and address emergent challenges. Figure 5 visualises the originated conceptual context as described above.

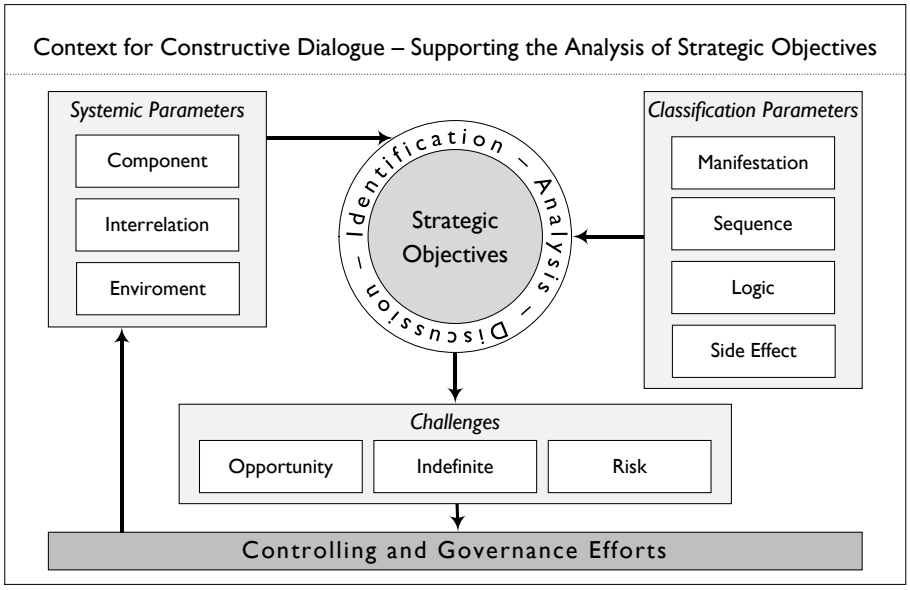

Figure 5: Originated Context for Constructive Dialogue about Strategic Objectives in Complex Systems

5 Discussion

Chapter 5 discusses the contributions of this study. First, it indicates the impact of the study's results on praxis in the complex planning context. Second, it similarly emphasises the academic implications. Third, it addresses methodical considerations related to the investigation and it summarises lastly opportunities for further research.

5.1 Indications for Planning in Practice

This study obtained results from the Swedish implementation of a complex national planning for CIP during cases of power shortages. The analysis of documentations of the *STYREL* case and interviews with municipalities, CABs and power grid providers have yielded findings on the complex planning system, its components and their interrelations, as embedded in certain environments. The findings thus offer new knowledge for improving the Swedish process and similar complex planning systems.

During the investigation, this study more closely examined interests, i.e. strategic objectives, which are involved in complex planning environments and which challenge the governance of complex systems, as presented previously. Three challenges were consequently identified: *Opportunities*, *Risks* and *Indefinites*. Positive effects were attributed to opportunities, while negative consequences were assigned to risks and a neutral impact was associated with indefinite challenges to governance. One suggestion resulting from this classification could be that governance of complex planning environments must focus on opportunities, i.e. a bundle of strategic objectives that mutually promote each other and whose means of achievement separately offer beneficial side effects for others in the bundle. Alternatively, governance may be advised to focus on risks that strategic objectives are antinomic or that the means to reach them provide conflicting side effects. Although both suggestions are reasonable, there might be availability constraints on resources such as time, money and knowledge, which would reduce the ability of governance to address both challenges comprehensively and simultaneously. Therefore, the strategic objectives that drive governance efforts in a complex planning environment warrant careful consideration. Furthermore, the strategic objectives that lead and are involved in a planning environment may be subject to changes in a period. Such changes highlight the need for regular re-evaluations, which also applies to the third challenge: the indefinites, i.e. strategic objectives that are compatible and provide neutral side effects. The evidence of *STYREL* related to CIP in Sweden implies that the conditions of the planning system change over time. For example, planners

change their positions, power grid providers expand the grid and new technologies or threats arise. Hence, strategic objectives that relate to complex planning must be regularly analysed to focus governance on the most important issues at a certain point in time and to facilitate a motivated refocusing when necessary. The conceptual framework explained in Section 4.3 provides an analytical tool for such an investigation which this study recommends for application even beyond the Swedish *STYREL* case.

5.1.1 Significance for the *STYREL* Case

This study horizontally and vertically decomposes the complex planning environment for CIP. The first decomposition delimits the complex system to stakeholders who are concerned with *STYREL* as system components and relations among them. The second decomposition of the case into hierarchical levels of planning facilitates analysis of the goals and means involved in the Swedish case. Thereby, the examination identifies interrelated strategic objectives and analyses their properties. However, it does not yet comprehensively consider all objectives that stakeholders may present to the governance of the Swedish planning. Time limitations restricted the empirical inquiry, but the provided context for a constructive dialogue can identify and characterise further stakeholders and strategic objectives.

The inquiry clarifies how the *STYREL* planning is anchored in local society by requesting local knowledge. Although this approach is intended to be enclosing and participative, the results indicate that the planning procedure only partly reaches out to the local society. In addition, the resulting plan is only used to serve power grid providers. Therefore, the process cannot be considered as fully developed. Instead, the procedure appears to be a well-established starting point for a more far-reaching approach that would include civic society and various actors that contend with the consequences of emergencies. This study assists with a conceptual system model (see Paper II) to identify relevant stakeholders. Such a proceeding can also facilitate an analysis of risks and consequences that a critical event can pose to particular groups, which in turn could inform an appropriate preparation of target-oriented response. Moreover, the framework for analysing the multi-level planning (see Paper III) specifies sources of uncertainty by various parameters that reveals a need for knowledge associated with the process, the decision-makers and other stakeholders. Thereby, this study provides a valuable tool to nuance the approach and address the particular issues seriatim. Thus, by developing more breadth and depth, *STYREL* is well positioned to become a strong planning approach that provides value to both power grid operators and national society. The provided models visualise the current situation and

surroundings of *STYREL* and can accordingly be used to explore information paths to identify critical interrelations and responsibilities between concerned actors. Evidence from this study indicates, for example, that informal information paths may exist between local planners and emergency services which support local preparedness planning. Such experiences from local instantiations can highlight the shortcomings of the procedure and the creativity of local planners to add value to their local community. However, such insights support a formal refinement of *STYREL*. The study results provide visualisation and structure for this refinement to horizontally and vertically explore the complex planning environment, i.e. the process co-ordination and hierarchical organisation. This may in turn align strategic objectives and responsibilities as well as concretise measurements for information security in the complex system of planning for CIP. Moreover, clearance in horizontal and vertical structures could reduce lacks of knowledge (see Paper III). Further development would both clarify process activities and responsibilities and improve resource allocation at the local, regional and national levels.

The complex and quickly changing environment of national planning for emergency response in a case of a power shortage (McGuire 2006; Poister 2010) implies that monitoring the open system is necessary for process adaptation to changing requirements and demands. The conceptual system model (see Paper II) represents the complex planning environment, limited to the *STYREL* context, from an overall perspective. This entry point encourages in-depth analysis of certain environmental conditions while maintaining a holistic perspective, and it offers information about the development of *STYREL* and the related means for emergency response. Evidence from the interviews can direct such governance efforts because the experienced conditions of the current planning environment indicate areas for further improvement, such as collaboration inside and between organisations, communication alongside the planning, and comprehension of the problem situation, which the planning targets. Hence, the insights obtained through this inquiry offer significant perspectives on the complex planning environment that is dedicated to CIP from effects of a power shortage. This knowledge can support governance to enhance a shared understanding of the planning context among stakeholders who are involved in and affected by *STYREL*.

In view of the discussion above, such governance efforts in the context of the *STYREL* case are encouraged to address the following.

- Identification of strategic objectives
- Assessment of strategic objectives on relevance and feasibility
- Involvement of further actors and co-ordination of all actors

- Risk and consequence analysis (also further emergency power supply)
- Prioritisation and integration of objectives, goals and means
- Communication and control of preferred strategic objectives
- Visualisation of structures, interrelations and environment
- Alignment of responsibilities and information security measurements
- Development of the (reference) process and resource allocation
- Collective learning: hands-on training and knowledge exchange
- Development of the decision-making processes
- Continuous improvement of governance

5.1.2 Relevance for Similar Planning Systems

This study not only provides insights that encourage national governance regarding the *STYREL* case but also further inspires similar planning procedures regarding the complexity of the planning environment or within another national or sectoral context associated with CIP. Thus, an important result of the case study is the report on the specific *STYREL* approach, which is inclusive of various elements within the system, such as stakeholders, concerns and hierarchical structures. Thereby, this study exposes the Swedish-documented case to additional analysis, comparison and contrast with other planning procedures. The results demonstrate the role of the Swedish planning and decision-making process in a national multi-level planning for emergency response. These results indicate how the completeness of such emergency response planning may affect both the experienced benefit of the planning by various concerned stakeholders and an emergency response during a critical situation in the future. Lessons learned from such events can in turn inform future improvements of a planning process if evaluation measurements are in place. Thus, the results of Paper III (Section 4.2.3) provide an analysis tool for deeper investigation of similar complex circumstances. This can extend the specification of sources of uncertainty with parameters that appear vital in other cases.

The study further demonstrates how involved actors interrelate and collaborate in a certain system environment. It evidences the formation and implementation of planning for CIP in Sweden, which simultaneously illustrates the complexity incorporated in the approach. Experiences of the *STYREL* planning featured in this study can assist other national process developments with knowledge of such complex settings. The study also reveals shortcomings of the procedure, difficulties in identifying and prioritising key power consumers and benefits and side effects for further local and regional planning. Thereby, the study encourages a discussion and adaption of such procedures even beyond the Swedish context. To this end, it

additionally contributes models and frameworks which may be helpful for such analysis as entry points for refinement of nationally adapted approaches. This may facilitate an international alignment of overlapping responsibilities, for example in areas close to national borders. In prolongation, such alignment could initiate and reinforce shared efforts with respect to emergency services in such cross-border areas by means of mutual understanding and aligned strategic objectives.

5.2 Implications for Research

Apart from the practical implications, the study aims to contribute to the body of knowledge within the research field of complex (planning) systems. This study thus provides results with relevance for three main segments: the problem domain of CIP, the research area of governance of complex planning environments in general and the focus on strategic objectives in such planning in particular. In addition, the research undertaken in this comprehensive field builds upon knowledge in the area of interdisciplinary research methodology.

5.2.1 Problem Area of Critical Infrastructure Protection

The evidence obtained by this study confirms the difficulty of determining infrastructure criticality that previous research has disclosed (Fekete 2011). This challenge emerges from two major problems: the first is to identify relevant infrastructure assets and the second is to establish their importance. *STYREL* reveals that these problems remain even if the national problem is split into regional and local portions. Instead, a third problem with regard to co-ordination arises and includes the upwards aggregation of local prioritisations into regional and national plans and the downwards consideration of the implications of a national plan for regional and local planning. The literature review regarding *STYREL* has revealed an additive approach as the aggregation method in a collaborative setting to aggregate decisions about power consumers to controllable power lines. Thereby, the study imparts novel knowledge about a decision-making method in the context of national planning for CIP. Nevertheless, the potential impact of this decision method on emergency response during a power shortage situation could not be evaluated due to the absence of any evaluation measurements in the Swedish approach. However, interview findings suggest that entrusted decision-makers in the planning process do not experience benefits of the *STYREL* planning in their daily work in emergency response planning. The investigation of the strategic objectives of the planning reveals points of friction, such as different perceptions and requirements of stakeholders who

are involved in and affected by such planning for CIP. This study illuminates underlying mechanisms in the area of CIP, though it cannot yet be considered complete as a result of the complexity of the planning environment for CIP which, as the Swedish case indicates, involves various sub-systems and interrelations.

Apart from the challenge of determining infrastructure criticality and dependence on the power supply, developing a national planning process in a distributed environment with many concerned stakeholders requires a holistic view of the problem situation (Pescaroli, Alexander 2016). Therefore, the study has developed a Rich Picture (Figure 2) of the complex planning environment that is inclusive of concerned stakeholders and has identified interrelations. The conceptual model delivers new knowledge in accordance with the entire system of planning for power shortages in Sweden. This renders the Swedish approach assessable through international evaluation and comparison with other approaches. Currently, the Swedish approach appears unique in its focus on collaboration at the local and regional levels and its almost non-technical perspective. The study explains that this focus poses further challenges to CIP, for example the assurance of information security during planning, information storage and future usage of the plan. Therefore, the exploration of strategic objectives in this study can be a starting point for further investigation.

5.2.2 Research Area of Governance in Complex Planning Environments

The results of this study support the system perspective of complex planning environments as a precondition to inform governance through the identification of components and their interrelations in a certain environment. Moreover, it has identified stakeholders who are involved in and affected by the planning. The Swedish case exemplifies a complex, open system. A large number of actors in planning for CIP and various stakeholder interests diminish the boundaries of the system. An adaptive behaviour (Holland 2006) can be attributed to certain system components using interview-derived evidence. For example, local decision-makers may adapt activities according to available information and resources as well as an individual interpretation of the classification scheme. The system behaviour then becomes emergent and unpredictable. The investigation of the Swedish case emphasises and illustrates the usefulness of applying systems thinking onto complex planning environments for approaching and structuring such systems. The unique knowledge of this particular system can inform further investigations of systemic effects in such complex systems of planning, which may also involve international collaboration.

Apart from revealing stakeholders, applying the system perspective also illuminated interconnections between them and environmental conditions of the studied system. This new knowledge allows the Swedish case to be subject to further studies of complex systems governance. Therefore, one outcome of the study unfolds how the complex planning environment of the *STYREL* case can be structured as a multi-level and multi-agency planning problem (Figure 3). Such a structure can apply to the entire planning or divide the complex system into detailed sub-levels while maintaining a holistic perspective. This consistent analytical framework for multi-level planning represents a novel approach for structuring and investigating complex planning environments (Paper III). The proposed application to the Swedish case indicates that both an alignment of goals and co-ordination of appropriate means, among other elements, are important for developing such complex systems of planning.

Research on governance and strategic planning has emphasised the possible impact of an individual planner, who brings individual and contrary interests into decisions, on planning itself (Lovan et al. 2016; Mintzberg 1994). Evidence of *STYREL* indicates that governance must consider both the characteristics of a decision-maker and the surrounding planning environment. This study shows how these two factors interrelate with three sources of uncertainty due to lacks of knowledge about the planning process, the decision-making process and the direction and guidance alongside it. These sources of uncertainty, with specifying parameters, inform the novel analytical tool for the research field. Since this analytical tool stems from analysis of the complex planning environment around *STYREL*, further applications to other cases may extend the specification with additional parameters.

5.2.3 Focus on Strategic Objectives in Planning Environments

This study and former research have emphasised the relevance of stakeholder interests in a future system state, whether considered or not considered by a complex planning (Bryson 2004; Furlong et al. 2016; Metzger 2013; Schweizer et al. 2016). Particularly in a public planning constellation, where planners act as individuals or as participants in groups on behalf of an organisation, various interests are involved as strategic objectives. This study notes relevant stakeholders in the context of the investigated case, an outcome that also informs similar cases beyond the Swedish context. However, while this inquiry identifies stakeholders in the Swedish case from a high-level perspective, a more detailed decomposition may reveal additional stakeholder concerns.

This study argues that strategic objectives must be aligned throughout a national planning to reduce confusion related to complexity, uncertainty and ambiguity in the system. It thus demonstrates how the mentioned multi-level

planning framework supports the co-ordinated decomposition of such planning, and thereby facilitates the analysis of strategic objectives therein. The context for a constructive dialogue (Figure 5) more closely examines these strategic objectives through systemic and classification parameters. In doing so, the study provides a model for exploring challenges that strategic objectives pose to governance in complex planning environments.

5.2.4 Research Area of Interdisciplinary Research Methodology

This research on national planning for CIP evidences that such a complex planning environment can be considered a cross-disciplinary research problem through which researchers from different fields can learn from each other in a manner similar to the various actors in the investigated case. This study shows how using a multi-dimensional inquiry to apply multiple perspectives of such a research problem reveals not only overlapping areas but also a deeper and broader understanding. Moreover, experiences from researching the *STYREL* case have informed the development of the multi-perspective kaleidoscope (Paper IV), which supports a new methodology to design a multidisciplinary research strategy. This multi-perspective kaleidoscope illustrates an original method of narrowing the research focus to apply to a complex problem such as the Swedish case. Although the kaleidoscope has been used only once so far, application to other research problems may substantiate its usefulness and indicate subsequent improvement of the method components.

5.3 Reflections on Methodical Proceeding

As an overall method, a case study was selected to investigate the Swedish *STYREL* planning in detail. Two facts motivated this selection: first, the case appeared unique in its implementation, and second, the national context indicated complex and challenging circumstances (Remenyi 2012; Yin 2014). In retrospect, this selection of the research subject was appropriate because the addressed context of CIP has recently become a key security issue for modern societies. Therefore, the case could be representative and informative of similar circumstances in other countries. Interrelated issues, such as the challenges that strategic objectives pose to complex system governance, can apply to similar large-scale planning tasks with numerous stakeholders and interests. Nevertheless, given the number of actors in the Swedish case, the study limited the scope to actors and activities at the core of *STYREL*. Thus, the case study is not yet complete and suggests further analysis of units related to the case.

The case study employed several method components for data collection and analysis. Evidence was gained through content analysis of documents

and interviews on the case. This evidence informed the design of the previously presented conceptual models. Observations in the field and during interviews enriched the obtained knowledge. Although this proceeding enabled the study to tell a convincing story, it may not consider all experiences equally. Therefore, the data collection pursued evidence from both decision-makers who are charged with the planning and documentations from several levels of the procedure. However, not all documentations could be accessed due to information security issues, as the planning concerns the national security. Moreover, additional issues were associated with limited access to informants at municipalities; for example, not all participants could find time for an interview, or a post was vacant. These issues may affect the completeness of the data collection. The interviews were recorded and transcribed, which facilitated the subsequent content analysis. Documentations and transcriptions could be analysed similarly by applying specified parameters for analysis. This in-depth analysis revealed the presented evidence, though further parameters may yield additional deliberations that could motivate supplementary examination. The same applies to the conceptual models; since they are constructed for a specific purpose and audience, such circumstances limit the scope of these models. Hence, subsequent studies may inform improvements of the concepts.

5.4 Further Research

The previous discussion reveals several recommendations for further research. First, future research could examine additional stakeholder views to inform an in-depth analysis of strategic objectives that relate to *STYREL*. Such research could provide knowledge for the development of the Swedish planning and for similar complex systems in other contexts. Second, future research could address the information processing during planning for national CIP; resulting insights on information security issues could then inform adaptation of system governance. Third, the role of particular actors as attractors in the complex system may be a research topic to learn about order and adaptation processes and how system governance could address them. Lastly, further studies may apply the proposed models to analyse other complex systems, or particular issues within them, from a holistic point of view. The results of such analyses can facilitate a constructive dialogue among concerned actors to comprehend the importance of specific objectives, which can in turn align efforts during national or international complex planning in context even beyond CIP.

6 Conclusion

Chapter 6 briefly summarises this study and concludes the results with respect to the research questions. Thereby, it highlights the particular contribution of this thesis.

This study has investigated the *STYREL* approach in Sweden, which is part of a national emergency response planning against power shortages and intends to reduce consequences of such events for the belonging society. The inquiry particularly sought to investigate challenges that governance must contend with in such a complex planning system and its environment of CIP.

This study has collected evidence from several sources. The first was publicly available Swedish literature that reports on *STYREL*, which included legal regulations, reports and guidelines. Another source was interviews with responsible individuals at municipalities and CABs and some respondents at power grid providers. Lastly, observations during contacts with respondents, the interview situations and work environment visits enriched the evidence.

This summary compiles the study from a holistic perspective of the case. Each of the included papers assesses specific aspects of the research questions. By applying multiple method components, this study has yielded a multifaceted understanding of both the systemic conditions associated with *STYREL* and the conduct of research in such complex planning environments.

Thereby, the results raise awareness of the complex system of national planning for CIP, the strategic objectives that are associated with such multi-level planning and the combination of both that challenges governance of such complex planning environments. Although *STYREL* relies on the survival of and collective learning in the complex system over time, current governance has neglected to continuously foster the planning environment. This study indicates, for instance, that the system degenerates between process iterations while merely informal relations between individuals continue, and a utilisation of synergy effects revert to individual efforts. To address the systemic conditions of such planning for CIP, the study has demonstrated systemic thinking of such complex problems to consider interdependencies and information flows and to align objectives, goals and means in the national planning for CIP. The study thus contributes an extensive representation of the *STYREL* case to the research field of complex systems and their governance. This study additionally contributes a context for a constructive dialogue about the strategic objectives that challenge governance of such a system. This dialogue may in turn facilitate an alignment of planning and crisis management and encourage motivated risk communication to the wider public at the local, regional, national and international levels.

The study has examined the research questions as posed in Section 1.3. Chapter 4 outlines the findings in detail, which are concluded below.

RQ 1: Which conditions represent the complex system of response planning for power shortages and its environment of CIP in accordance with STYREL in Sweden?

From the system components view, *STYREL* is a long-term planning in the context of Swedish CIP that alternates with long stand-by periods between iterations, during which responsible individuals change their working tasks or positions. Organisational knowledge and experience of the proceedings consequently disappear, which is a major problem that organisations have insufficiently acknowledged. Clarity of objectives, goals and means thereby diminishes and necessitates completely new consideration in the next process iteration. Since experience levels have been inadequately addressed, decision-makers in the distributed approach in Sweden must rely on their own perceptions and determinations of proper local proceedings. Such an adaptation can trigger an emergent system behaviour during the next iteration of *STYREL* or subsequent preparedness planning. Although the large-scale national planning for CIP against power shortages involves many actors, it neglects to stipulate further participation of non-governmental organisations or citizens for enhancing the resilience of the society, i.e. the capability to respond to critical events, such as power shortages. Thus, this proceeding results in uncalculated consequences.

RQ 2: Which sources of uncertainty and strategic objectives emerge from multi-level planning in general and the complex system of emergency response planning for CIP and the interrelated STYREL process in Sweden in particular?

Strategic objectives affect the outcome of planning and its benefits during an emergency because planning for CIP, such as *STYREL*, involves various interdependencies, stakeholder interests and plans to mitigate consequences. This study has demonstrated that splitting a complex national planning task into local parts does not sufficiently reduce its complexity and uncertainty. The study has particularly characterised three sources of uncertainty in multi-level planning that relate to lacks of knowledge: (1) *The complex planning process* refers to the tactical and operative planning, i.e. the reference process development and a related sourcing; (2) *The decision-making process* addresses the execution of a planning and the production of a plan; (3) *The direction and guidance* alongside (1) and (2) highlight the relevance of governance of complex planning systems for aligning strategic objectives, goals and means in and between these processes. This study has discussed how governance can address and reduce these sources of uncertainty due to lacks of knowledge; however, further stochastic uncertainty hampers the estimation of consequences, such as the duration of a power shortage and the value loss

for a modern society. Hence, given such difficulties in estimating the cascading consequences of a national power shortage, governance must acknowledge the complexity of the problem that national planning for CIP intends to address. Therefore, the study contributes systemic thinking to governance of complex planning environments.

RQ 3: How do the implications of these systemic conditions and strategic objectives affect governance of the complex planning for CIP in Sweden?

As this study has unfolded, inadequate complex system governance of *STYREL* leads to a degenerated system state that, apart from wasting resources, implies an overdependence on attractors who dominate the decision-making process. These can be experienced individuals or established results from previous planning iterations. The systemic conditions of this complex planning yield particularly strategic objectives, which challenge governance as *opportunities*, *indefinites* and *risks*. Hence, governance acquires significance both (1) for reducing the complexity associated with the ambiguity and uncertainty due to lacks of knowledge and clarity and (2) for aligning strategic objectives, goals and means. Thereby, governance must respect and address the specific characteristics of complex systems that integrate humans in order to produce system viability via the provision of communication, co-ordination, integration and control.

This study has revealed a significant need to clarify the aims of a planning, which can properly delimit the process, facilitate the development of controllable structures and install co-ordinated information paths. In CIP, such clarity fosters information security and an integrative transfer of the result of one planning to a subsequent one. Moreover, by deliberated feedback and knowledge exchange, governance must mitigate system degeneration over time and between process iterations. Establishing sustainable structures, such as a national organisation structure, assists with maintaining synergy effects, which may further improve the quality of planning results. Thereby, governance could attract and control the spontaneous order of the system.

The non-linearity of cause and effect in both planning and crisis encourages governance to raise awareness of the complexity of planning for CIP due to interdependencies and various requirements. Decisions in such complex systems rely on a shared vision among stakeholders regarding strategic objectives, which necessitates their regular analysis and communication. This study particularly contributes a context for a constructive dialogue about strategic objectives that encourages their alignment by concentrating governance efforts on the relevant bundles. Such an integrated understanding of interpretations of a complex situation can also inform civic preparedness and enhance evidence-based risk communication to the public.

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