

Left in the Dark: Obstacles to Studying and Performing Critical Infrastructure Protection

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Abstract: This paper highlights major methodological obstacles to studying and performing critical infrastructure protection (CIP) in general and CIP governance in particular. The study simultaneously examines a research project on and practice in the context of Swedish CIP. The complex planning approach of interest is called *STYREL*, a Swedish acronym for Steering Electricity to prioritised power consumers. It aims to identify and prioritise power consumers of societal importance, collectively referred to as critical infrastructure (CI), to provide an emergency response plan for the event of a national power shortage. Methodologically, the investigation uses material from document studies, interviews and a survey, which involved many actors from the Swedish case. For the analysis of the methodological obstacles, this study applies an abstracted research and development process that encompasses four steps: data collection, data assessment, decision-making and evaluation. The paper mutually maps the insights from the research project to the empirical evidence from the case study. Through this reflective analysis, the findings contribute to a deeper understanding of the challenges that significantly impede research and practice in the context of national and international CIP, for example, insufficient information sharing and knowledge exchange among parties, a lack of integrated and advanced methods, and uncertainty in policies that induces a variety of local approaches. In addition, since empirical research on implemented CIP plans is limited, this paper addresses this gap. It reveals five general obstacles for both research and practice: a) the access to high-quality data, b) the loss of knowledge over time, c) the interpretation and evaluation of processes and methods, d) the transferability and comparability of data, results and insights; whereas all culminate in 5) a lack of collective intelligence. The accumulation of these obstacles hinders a detailed assessment of decision-making for CIP and its consequences on society. For this reason, this study emphasises the need for enhancing mutual understanding among the various parties in the area of CIP while respecting relevant security issues when inventing novel methods that facilitate collective intelligence.

Keywords: Research methodology, Critical infrastructure protection, Information security, Governance network research, Swedish crisis management, National emergency response planning

1. Introduction

The use of mixed methods is increasing in many disciplines, including the study of critical infrastructures (CI) (Spousta and Chan, 2015; Bentahar and Cameron, 2015). However, previous reviews of methodologies for critical infrastructure protection (CIP) reflects that risk management frameworks mainly constitute the foundation for national plans on CI (Yusta, Correa and Lecal-Arántegui, 2011) and that a large portion of literature in the CIP field contain no description of the actual research process or epistemological position (Große, 2020). Applied methods include simulation techniques to model the dynamic behaviour of CI or estimate risk mitigation strategies as well as rating matrices to describe the current state of the CI. Moreover, information exchange regarding the modelling and implementation of CIP plans is rare but encourages co-operation between public and private organisations to classify and conduct comprehensive inventories of CI (Yusta, Correa and Lecal-Arántegui, 2011). Research has also identified deficiencies in knowledge management methods for public-private partnerships, such as CIP, which necessitates further studies to improve information integration methods (Cui, et al., 2018). The design of new research method artefacts (Venable and Baskerville, 2012) has over the last decades included configurational techniques such as QCA, Qualitative Comparative Analysis (Rihoux and Ragin, 2009), and inductive approaches such as CQR, Consensual Qualitative Research (Hill, et al., 2005). However, to advance methods such as collective intelligence (Peeters, et al., 2021), there is still a need to understand the methodological proceedings in complex environments, such as alongside public-private cooperation for CIP.

Thus, the purpose of this study is to contribute to a deeper understanding of the obstacles that significantly impede research and practice in the context of national and international CIP, for example, insufficient information sharing and knowledge exchange among parties, a lack of integrated and advanced methods, and

uncertainty in policies that induces a variety of local approaches. Therefore, the present paper aims to highlight some major methodological obstacles to studying and performing CIP in general and CIP governance in particular.

This paper derives from a research project in the Swedish context. First, it addresses the methodological concerns that emerged during the project, which similarly challenged the actors in the studied CIP approach. Second, the study further analyses the impact of these methodological obstacles on the outcomes of both the research project and the examined planning for CIP. Thus, the focus is on the four-step process of data collection, data assessment, decision-making and evaluation that unites the proceedings within the research project and the practices in the Swedish case. Due to the advanced stage of this complex case, a representation of the methodological obstacles is of major interest to research on methodologies for complex systems analysis, policy makers and practitioners in the CIP field and similar contexts, including and beyond the Swedish case.

The following investigation is based on a case study of the long-term process called *STYREL* that concerns an approach for CIP against power shortages in Sweden. Modern societies' increasing dependency on electricity induces the risk that they will be unable to maintain essential societal functions in the event of a blackout or power shortage. Therefore, Sweden has developed the national planning process *STYREL* (Swedish Energy Agency (SEA), 2014). This approach involves a multi-level system of public and private actors from different levels in society, whereas county administrative boards (CABs) co-ordinate between municipalities within counties and a considerable number of national agencies (Große and Olausson, 2018). During the *STYREL* process, the actors sequentially identify and prioritise CI and produce a ranked list of power lines that power grid operators (PGOs) shall prioritise if the power supply must be limited by order from the national operator.

Since CI can be described as a complex system-of-systems (Gheorghe, et al., 2006), attempts to protect CI must also be characterised as complex. Accordingly, such CIP needs to address the systemic challenges that the complex interdependencies among the various system components produce (Große, 2018). The studying of a CIP approach such as *STYREL* speaks to the literature on project management (Blomquist, et al., 2010). The methodology used within the research project situates itself within a process framework and therefore attempted to describe how the process of planning could be understood (Blomquist, et al., 2010). The process framework is reflected in the empirical approach which involved a triangulation of different types of material such as documents, interviews and a survey. Recent research has demonstrated that the complexities of the CI systems pose not only a significant challenge to emergency response planning practice but also challenges traditional methods of analysis (Zio, 2016). However, since empirical research on implemented CIP plans is limited, this paper addresses this gap and reveals certain obstacles for both research and practice. In particular, the study identifies five general obstacles to the studying of CIP: a) the access to high-quality data, b) the loss of knowledge over time, c) the interpretation and evaluation of processes and methods, d) the transferability and comparability of data, results and insights; whereas all culminate in 5) a lack of collective intelligence.

After this introduction, Section 2 provides a brief background to this study and the research in the CIP field. Section 3 describes the interdisciplinary approach of the project and the proceeding of this study. Section 4 presents the methodological obstacles that emerged during both the study and the CIP planning context. Section 5 discusses implications for CIP planning, such as *STYREL*, and for research in the context of CIP and crisis management. Section 6 concludes by emphasising areas for improvement, which could expand the comprehensiveness of the obtained knowledge when studying CIP.

2. Background

2.1 Power supply and critical infrastructure protection

The power supply sector is considered central to the other sectors of CI because it constitutes a precondition for their proper functionality (Rinaldi, Peerenboom and Kelly, 2001; Yusta, Correa and Laca-Arántegui, 2011). Recent studies have investigated the prevention and restoration of power distribution systems after a failure (Negnevitsky, et al., 2013; Tortos and Terzija, 2012), the cascading effects of technical failures (Hines, Balasubramaniam and Sanchez, 2009; Vaiman, et al., 2013), and the resilience of power distribution systems (Maliszewski and Perrings, 2012). Apart from investigating the economic costs of power outages (e.g. Küfeoğlu and Lehtonen, 2013), other studies have encouraged advances in society's resilience to cope with rare events that have catastrophic potential (Boin and McConnell, 2007; Wright, et al., 2012). Research on power outages in Sweden revealed that actors in municipalities and PGOs expected households to be prepared; however,

households did not clearly understand that they had such a responsibility (Palm, 2009). In addition, since there have been few severe power outages in the past, people responsible for preparedness and response planning in municipalities (Enander, Hede and Lajksjö, 2015) and civil defence in CABs (Wimelius and Engberg, 2015) have limited experience with such events. Previous research in the context of CIP has revealed that inadequate information channels during the process, organisational biases during decision-making, and lack of mutual understanding hamper cross-functional collaboration and coordination during preparation and crisis management (Powley, 2009; Pramanik, et al., 2015; Odlund, 2010; Große, 2019).

2.2 Swedish planning of CIP – STYREL

To facilitate a better understanding of the complexity of research and practice in context of CIP, a brief description of the Swedish circumstances follows. In Sweden, power is produced mostly in the North, while most of the power consumption occurs in the more populous southern parts of the country. This could lead to power shortages if the power transmitted cannot fulfil power demand. Considering this risk, the SEA developed the national planning process *STYREL* between 2004 and 2011. This approach aims to produce a plan for directing power to prioritised power consumers during a national power shortage. Similar to the overall Swedish crisis management system, *STYREL* engages a considerable number of actors at local, regional, and national levels from both public and private sectors (Große, 2018). The goal is to protect society from the adverse effects of disturbances in electricity supply. This CIP planning identifies electricity-dependent infrastructure such as buildings and facilities that provide societally important functionality. *STYREL* applies the eight-point scale in Table 1 to identify and prioritise CI. The pilot of *STYREL* run in 2009 and its first and second rounds occurred in 2010/11 and 2014/15, respectively. The plan was to conduct the third round from 2019 to 2021; however, because of the worldwide COVID-19 pandemic, the SEA decided to postpone the third round. However, since the implementation of *STYREL*, there has not been any electricity shortage situation calling for the operation of *STYREL* by manual load shedding. Therefore, it is not possible to evaluate whether the planning system works as intended. Figure 1 demonstrates the proceedings followed in the second run (SEA 2014):

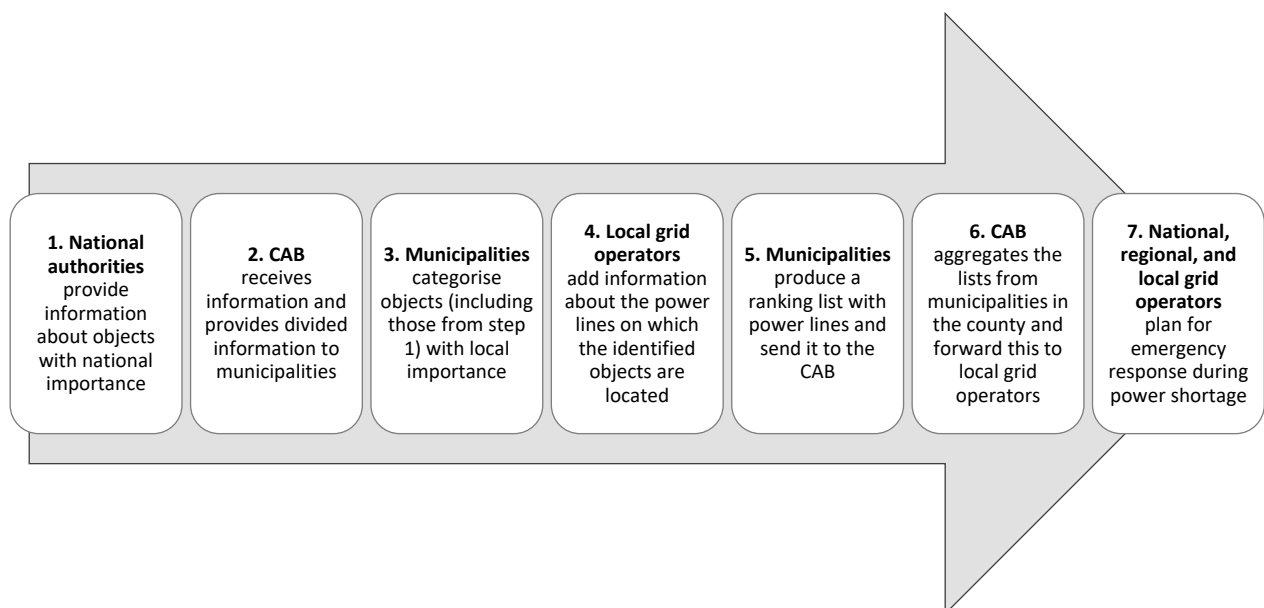


Figure 1: Reference process of *STYREL* as proposed by the Swedish Energy Agency (SEA, 2014)

First, the Swedish Energy Agency (SEA) invites relevant national agencies to make an inventory of CI that they individually operate across the country. In adherence with the scale shown in Table 1, the importance of each identified asset and its functionality for society apply to each CI. The agencies then provide information about these classified assets to each CAB responsible for the location of the CI (1). The CABs in turn organise the lists from the agencies into sections corresponding with each municipality’s geographical area of responsibility (2). CI of national and regional importance is included in the additional local proceedings at the municipalities, which make an inventory of local circumstances to find and classify CI according to the above-mentioned scale (3).

Table 1: Priority Classes of Critical Infrastructure (Swedish Civil Contingencies Agency [MSB], 2010, p.10)

Class	Electricity consumers that have/represent:
1	Significant impact on life and health in a short time frame (hours)
2	Significant impact on vital societal functions in a short time frame (hours)
3	Significant impact on life and health in a longer time frame (days)
4	Significant impact on vital societal functions in a longer time frame (days)
5	Significant economic value
6	Significant importance to the environment
7	Significant importance for societal and cultural values
8	Others

During the local ranking, local PGOs assist with information about how power consumers link to power lines (4). The prioritised CI are then merged in spreadsheets using an additive approach in the ranking of controllable power lines. After their final decision on the ranking of power lines, municipalities return the revised document to their CAB (5). The CAB assembles the lists from the municipalities in a similar manner and compiles their final ranking, which is sent to the national PGO and, in separate sections, to local PGOs (6). Local PGOs must subsequently use these lists in their planning of manual load shedding in cases of power shortage (7). Currently, ten of the 160 PGOs in Sweden are responsible when disturbances occur in the power grid. These PGOs must maintain preconditions that enable them at any time – by order of the national operator – to reduce power consumption based on demanded volume. This consumption reduction must be effectuated within 15 minutes of receiving the order and should adhere to the *STYREL* plan as much as possible.

3. Data and method

3.1 Material: Data collected during the research project

The research project applied a mixed-method approach (Maxwell, 2010). The data collection included publicly available documents, semi-structured interviews, and a survey, which enabled data triangulation (Gerring, 2007). Additionally, partial studies (Danielsson, Nyhlén and Olausson, 2020; Olausson, 2019; Große, 2017; Große and Olausson, 2018; 2019; Große, 2019; 2018), field notes, reflections, internal meeting protocols, and individual experiences of involved researchers along with the progress of the research project enriched the material basis of the present study (Bryman and Bell, 2015).

The document study investigated preparatory materials regarding the planning of the pilot in 2009 (CAB Blekinge, 2009; CAB Dalarna, 2009) and the first round of *STYREL* in 2011 (CAB Stockholm, 2012), which included public investigations and reports, instructions, handbooks produced for the policy-making process, and available evaluations. Initially, the document study also planned to include real municipal-, regional-, and national-level planning documents from the two rounds of *STYREL* to assess societally important objects throughout the different steps of the planning process. However, the results ultimately revealed that their inclusion was not possible due to secrecy, and that the information was lost and obsolete (see 4.2.2).

The interview study selected three counties, one representing the rural countryside, one including heavy industry close to the capitol, and one including one of the three major Swedish cities. The interviews involved four, 47, and 15 participants representing the CABs, municipalities, and PGOs, respectively. Excluding one, all 66 semi-structured interviews were conducted at the interviewees' ordinary workplace and lasted one hour on average. Together with the document study, the recorded and transcribed interviews constituted a valuable source for subsequent analyses and the survey.

To broaden the analysis with particular aspects such as concrete proceedings and coordination at the regional level, the survey involved all 21 counties in the first step. The coordinators received a link to a web-based questionnaire, and 15 responded. The second step extended the data collection and addressed the 10 PGOs that perform emergency measurements to stabilise the power grid during the initial phase of a national power shortage. Representatives of all PGOs answered the survey in a physical meeting.

3.2 Analysis: Four-step model for investigating obstacles

This study applies a four-step model to analyse systematically the obstacles facing research and practice in the CIP context. Since CIP is a developing multidisciplinary research field, the analytical framework shown in Table 2 applies an inclusive perspective on an abstracted research and decision-making process.

Table 2: Analytical Framework

Step	Definition	Methods and Components
Data collection	concerns access to data and textual material	Documents Interviews Survey
Data assessment	involves the possible analyses of data and textual material	Qualitative text analysis Quantitative data analysis
Decision-making	regards adaptation with a progressing process	Selection Prioritising Aggregation
Evaluation	addresses the quality and relevance of results	Validation Development

The reflective analysis concentrates on methodological obstacles to studying *and* performing CIP and its governance. Therefore, the study classified the identified issues according to the analytical framework, arranging them with reference to both processes: the research project and *STYREL*. The combination of qualitative and quantitative materials as well as analysis methods yielded a comprehensive understanding of the obstacles that emerged repeatedly from the study in the CIP context (Venkatesh, Brown and Bala, 2013). The subsequent section details the main obstacles that affected both the study during the project and the actors during the Swedish CIP planning.

4. Methodological obstacles to research and practices of CIP

In accordance with the outlined framework, this section considers the methodological obstacles that significantly impede research and practice in the context of national and international CIP. The analysis highlights the impact of these problems on both the research project and the underlying *STYREL* process.

4.1 Obstacles to data collection

4.1.1 Access to documents and their content

The publicly available documentation regarding the creation and development of the Swedish planning is fragmented. Some documents provide different versions of the priority classes during the development process and others discuss considerations of necessary regulations associated with the planning process. The study found neither records of the development process nor evaluations of the second round of planning. This suggests that such documents do not exist, are classified, or that the owner does not want to share this information or has not considered sharing it.

The handbooks and guidelines provided by the nationally responsible SEA provided an easily accessible entry point into the planning process and templates used by the actors for planning and information sharing during the process. However, the instructions did not elaborate on the concrete proceedings of the planning process. Although the actors had control over their own part in the process, they had limited knowledge and lacked information about the other steps in the process.

Moreover, the document study included evaluations of the *STYREL* pilot run and the evaluation of the first round. Despite the project's goal, it was not possible to include real planning documents from the actors due to information security concerns. The actors were highly uncertain about the classification of the information and documents. In some cases, this information, which has been mostly stored offline, could not be found and was thus inaccessible to not only the researchers in the project, but also the entrusted officials.

However, the available documents have contributed to our understanding of the *STYREL* process from its commencement until now. This includes how and why *STYREL* was designed, which objectives the process targets, and how the pilot and first round were completed. This initial understanding became important for the interview study, for example, for when participants referred to the pilot and the first full-scale run. Notably, the second

round lacks any kind of evaluation, and none of the coordinating actors or any central instance collected any documentation or evaluation from the participants in the process. One obstacle to structured data collection from important documents is the variation in the content of the documentation between the actors. Moreover, some documents were publicly available, whereas other types of documents and information were undetectable. The interview study could not associate any systematic knowledge management with the *STYREL* process. Since knowledge from process developments and earlier rounds of planning is not systematically organised, such incompleteness arguably affects the continuity of the process. This implies that officials, particularly newly appointed ones, need to cope with information scarcity while executing the planning. During the following interviews, the insufficient documentation became obvious (Danielsson, Nyhlén and Olausson, 2020).

4.1.2 Access to participants and their institutional knowledge

The interview study first consulted the coordinators at the CABs in the selected counties. Their knowledge and experience varied based on their individual involvement in the planning process. Two of the coordinators had been involved in both rounds of *STYREL*, and one of them had been in another county during the first round (see Olausson, 2019). The other two coordinators participated in only the second round, and one of them had previously been responsible for the process in one of the municipalities in the county. This implies that while all the coordinators had experience with the planning, the knowledge of one of them regarding *STYREL* in their specific county was limited to documentation from the previous round and hearsay regarding the first round in the county. The subsequent survey discovered that 58% of all coordinators had never participated in *STYREL*.

Two or three years, respectively, had transpired between the first round of *STYREL* and the interviews with the security officers at the municipal level in 2016 and 2017. More than 40% of the interviewees had not participated in any of the *STYREL* rounds, and about one-fifth participated only in the second round. Before the interview, many had contacted their predecessors to acquire knowledge of the process. Staff turnover became an obvious obstacle; in many cases, the predecessors had retired or moved to another position. In some cases, municipalities had engaged retired public officers on a consultant basis to prioritise the identified CI or assist in local processes to mitigate the lack of knowledge. Additionally, some of the security officers gained knowledge through documents of the first round, and others derived their knowledge from colleagues who had limited experience in the two rounds. This implies that knowledge of *STYREL* is based mainly on others' experiences and hearsay about the process. Such deficiencies may explain one reason for the lack of evaluations from the second run.

The interviews with the PGOs involved representatives from national, regional, and local PGOs. At least 40% of the representatives had not participated in any of the *STYREL* planning rounds, and two had been involved only in the second round. Those who participated in both rounds showed considerably different levels of experience. One of the most experienced retired on the day of the interview, which constituted a unique opportunity for the successor to gain first-hand knowledge. Some representatives demonstrated comprehensive knowledge of their local power grid, for instance, by memorising the most critical objects of the grid. Most often, the local PGOs reported good co-operation with the security officers in their municipalities, and information sharing occurred personally between them in already established networks.

During one interview involving both security officers from the municipality and the representative from the local PGO, both actors' limited knowledge and understanding about the other's work with *STYREL* became apparent.

4.1.3 Distribution of survey and participation

Since the regional level maintains a central role as the coordinator in *STYREL*'s top-down and bottom-up approach (Große and Olausson, 2018), the survey focused on perceptions regarding co-operation and decision-making at the regional level. The aim was to distribute the questionnaire at a joint workshop organised by the SEA. Because of poor participation, we emailed a link to an online version of the survey to the coordinators who had missed the meeting. While the participants in the meeting spent time focusing on the planning process and interconnected obstacles in a group setting before filling out the form, the respondents to the online survey may have had another attitude when answering the questionnaire. Furthermore, six of the coordinators did not respond to the survey, possibly because the addressed person had been replaced by someone unknown to the researchers due to staff turnover.

In the second step, the survey was adapted to the PGO's role in the planning process. All addressed PGOs responded to the questionnaire after the survey was distributed during a physical meeting. Currently, only 10 out of 160 PGOs meet the requirements to respond rapidly to the event of a national power shortage, which implies that this might affect the comprehensiveness of the data collection, similar to the proper application of the planning results for CIP during such an event.

4.2 Obstacles to data assessment

The interdisciplinary project aimed to apply a variety of qualitative and quantitative methods to analyse the collected data (Maxwell, 2010). This research design should contribute to our understanding of the proceedings and concerns regarding collaboration in the context of CIP and further our knowledge about the decision-making process and information processing. However, the obstacles to data collection had consequences for data assessment.

4.2.1 Understanding of the planning process

To substantiate the understanding of the process, it was important to depart from the government investigation, *A safer society* (SOU [Official Reports of the Swedish Government], 1995), which identified power supply as one of the critical areas for national security and development in Sweden. Two years later, the *Vulnerability and Security Assessment* issued the report *Security in a New Era* (SOU, 2001), which discerned a change in the common threat scenario and an increased vulnerability of technical infrastructure, both of which would require stronger focus on reliable power supply. First, however, until the aftermath of the blackout in Sweden and Denmark in 2003 and the following evaluation by the Danish PGO, the compilation of a ranking of power consumers to prioritise during such events was encouraged (Elkraft System, 4.11.2003, p.6). Since 2004, the SEA has been responsible for the creation, design, and development of *STYREL*.

The qualitative analysis of *STYREL* documents faced challenges related to language, interpretation, and level of detail. Although the collected data and material are in Swedish, the usage of language differs. For example, regulations use a specific terminology, whereas public documents produced by municipalities often use colloquial language and tend to omit details. Such obstacles illustrate that the qualitative analysis of documents involves both interpreting unclear text passages and modifying the level of detail in accordance with research objectives.

The document analyses revealed that the planning process underwent major changes involving information sharing between municipalities and CABs from the first to the second execution of the process. Questions emerged about the reasons for these changes and their possible consequences for the *STYREL* process and its result. Furthermore, the handbook for the second round provided enhanced clarity and revealed that some process development occurred after the first round. Nevertheless, the handbook describes the process at a general level; therefore, the concrete proceeding regarding the several actors remains unspecified, which raises further uncertainties about the underlying objectives, concrete activities, and governance of the multi-level planning system. These considerations informed the preparations of the subsequent interview study.

The interviews confirmed that experience and knowledge faded between the planning rounds. One major reason for this obstacle is the long period that elapsed between the rounds of the planning process, during which staff turnover contributed to the loss of information. Because of the lack of knowledge management, new personnel lacked information about this planning process until the new process commenced. Another reason is that the documentation from previous rounds served as the foundation for the next one. Security officers often assumed that they could depart from such documents in their planning task. However, it was not possible to assess the quality of these documents. Some of the interviewees displayed a copy-and-paste behaviour rising from trust in the work of their predecessors and a limited comprehension of *STYREL*.

The interviews revealed that preconditions and requirements differed notably among the representatives from the PGOs. Apart from the operation of regional grids, larger companies are responsible for providing electricity to consumers in up to 120 local grids. Additionally, PGOs must ensure a certain level of information security due to legal regulations imposed on operators of CI. The exchange with municipalities impelled PGOs to perform intensive technical and manual processing of information. These preconditions provided obstacles that hampered not only closer co-operation and information sharing between many PGOs and municipalities, but also further analyses by both actors. Such conditions imply that larger PGOs, which are also certainly responsible during a power shortage, depend more on the reliability of public actors' work than smaller PGOs.

4.2.2 Statistics about the process

The restricted access to real planning documents constituted an insurmountable obstacle to mathematical and statistical analyses. Instead, modelling of the process departed from the current implementation at a theoretical level. Moreover, the aforementioned changes between the first and second rounds would have rendered it impossible to trace a prioritised object through the planning process. This scarcity considerably reduces evaluations of the preservation of the initial preferences of decision-makers during the different stages of *STYREL* (Große, 2019).

Another obstacle to the quantitative analysis of the possible consequences of a power shortage for society is that the amount and the particular location of the required power supply reduction will vary based on the particular requirements of a specific emergency. Consequences, in turn, depend on further aspects like the power demand of CI, the implemented preparation measures, such as emergency power aggregates or reserve capacities elsewhere, and the time required to restore power. Taking into account all these highly uncertain aspects for estimating the possible consequences for society was therefore beyond the capacity of the project, which indicates that this obstacle also applies to *STYREL*.

Analyses of metadata from interviews with security officers in municipalities yielded some descriptive statistics about the structure of the dataset, which was obtained through the survey. Furthermore, the analysis of the survey's first application revealed that 58.3% of the coordinators at the CABs had never participated in the planning process, 25% had participated in the second round, and *only 16.7% had participated in both rounds of STYREL* (Große and Olausson, 2018). More than half of the coordinators requested a better process with PGOs, and a similar number of respondents did not know how regional and national CI as well as cross-municipal and cross-regional power lines was handled during the process. Therefore, the second step of the survey study involved a group of PGOs, which confirmed a lack of experience; 44.5% of the PGOs had never participated in *STYREL*. The need for a more structured process with CABs was expressed by 77.8% of the PGOs. Regarding collaboration, the results revealed a considerably higher level of established networks in the realm of coordinators in CABs compared to PGOs. However, the opposite was revealed regarding the expected impact of the actor's work on society and the perceived level of knowledge. This may stem from the fact that compared to the CABs, PGOs possess better knowledge about the power grid but do not participate to a similar extent in the part of the process that identifies and prioritises CI.

4.3 Obstacles to decision-making

Since the research project took place between two rounds of planning, some research methods such as observations of collaboration and decision-making were not applicable. Moreover, it is highly likely that experience and knowledge of the process had faded as time passed after the process. However, as knowledge and experience increase during the proceedings, an experienced decision-maker can consider documentations as less important or even highly relevant. Therefore, there is a risk that both researchers and practitioners might overlook relevant information. Furthermore, the comprehensive understanding of the process that participants develop during the planning might differ from the retrospective reconstruction of the proceeding created by the researchers with the assistance of both experienced and new actors within *STYREL*. The *STYREL* reference process motivates adaptation to local requirements, which also includes adjustments to the level of knowledge and information access of specific decision-makers. This lack of clarity regarding local proceedings combined with inadequate documentation of previous planning rounds imposed high demands on decision-makers at all levels (Olausson and Nyhlén, 2017; van Dijk and Wilke, 2000).

As indicated, the research project could not address all uncertainties associated with Swedish CIP. However, the actors in CIP planning must contend with these obstacles, which highlights the relevance of developing methods that enable collective intelligence with cumulative knowledge in the field and inter-organisational learning capabilities, which in turn can improve decision-making under uncertainty. For instance, the interviews and survey revealed that the different actors used divergent and ambiguous terminology, which led to disparate interpretations of *STYREL*. Such divergent understanding because of uncertainty further produces individual interpretation and application of the classification scheme for prioritising CI at various levels, which could affect the results of the planning process. The different interpretations of the actors also relate to their area of responsibility. For example, the PGO interpretation reflects a trained focus on power supply and indicates that they did not identify and prioritise CI to a similar extent as the municipalities and CABs. However, the perceived lack of co-operation and the low rate of completion in terms of the final manual-load-shedding planning (60%

of all 160 PGOs) imply that the PGOs felt hindered when applying the results of *STYREL* to the final decisions on enhancing CIP by ensuring power supply to prioritised CI during a power shortage.

Understanding the complex nature of such decision-making and the systemic consequences that result from it emerges as an essential precondition for the development of appropriate processes and methodologies. In order to enable practitioners to anticipate such critical decisions, more advanced but applicable methods for such systems analysis are required (Peeters, et al., 2021).

4.4 Evaluation and development issues

The collection and assessment of data and the decisions made before, during, and subsequent to research in the project as well as in the planning for CIP provide certain conditions for evaluating and developing the processes. In the *STYREL* context, documentations of previous processes and the current one constitute input to upcoming processes. The review of literature in the field of CIP indicated that the Swedish process seems to be unique in its almost non-technical perspective of electricity transmission and its method of identifying and prioritising CI. This specific nature provides both research opportunities and obstacles. First, *STYREL* is an established process that has been executed in full-scale on two occasions. In addition, the number of participants, the lengthy planning process, and *STYREL*'s position within national and international CIP and crisis management efforts have attracted further research interest. Second, the singularities of *STYREL* are obstacles to comparisons with approaches in other sectors or countries. Similarly, the aforementioned lack of regulation regarding regional and local proceedings during the process resulted in a multitude of approaches, which hampered evaluation and hindered the actors in comparing their proceedings with those of similar actors or the first round. In some cases, minor revision preceded the use of the documents from the previous planning input data, which may also explain why no evaluations of the second round appeared during the initial document study. However, because information quality indicators are absent, it is difficult to assess the extent to which the available input can be perceived as reliable and reflecting reality. This scarcity implies that the built-in removal of information during the planning process creates a notable obstacle to evaluations of the preservation of initial preferences alongside the process, which also raises further obstacles to the integration of *STYREL* in other CIP and crisis management efforts at local, regional, and national levels.

Although the research project provided insights that can support further development of the process, the development of the third round of *STYREL* did not involve researchers or results from this project. The extent to which the results of the partial studies have contributed to the next rounds must be part of a subsequent project that scrutinises the updated handbook and proceedings of the participants. The current project observed a strong conviction among the actors that both CIP and *STYREL* constitute vital tasks for safeguarding daily life, civil protection, and crisis management. Consequently, the majority of the participants willingly provided their time to discuss experiences and obstacles. They expressed strong expectations for the improvement of the approach with respect to the considerations in this paper, which highlighted the apparent obstacles in nation-wide planning for CIP beyond organisational aspects. As mentioned, the document study could not obtain publicly available documentation about further improvements of the *STYREL* reference process. Nevertheless, the project results concerning collaboration, information processing, and decision-making during *STYREL* enable both research and practice to address obstacles to CIP at all societal levels.

5. Implications for Advancements in CIP

The reflective analysis of the methodological obstacles, which mirrors the proceedings of research in practice, highlights that CIP practice and the research in this context must contend with similar challenges. In particular, five general obstacles emerge from the analysis of the case and the research on it. These obstacles include a) the access to high-quality data, b) the loss of knowledge over time, c) the interpretation and evaluation of processes and methods, d) the transferability and comparability of data, results and insights; whereas all culminate in 5) a lack of collective intelligence.

First, the access to high-quality data is important not only for the CIP practice, but also for the application of mixed-methods in case studies and the development of advanced methods, including artificial intelligence (Peeters, et al., 2021). However, information security appeared to be a crucial aspect in the context of CIP. For example, relevant information regarding power demand and supply is often classified; therefore, it is difficult to share information between organisations or even within the same organisation, which may also build obstacles to international efforts (Fritzon, et al., 2007). Limited access to data built a major obstacle to the research

project. Data and materials that are important for such empirical studies are significantly limited for externals such as researchers due to information security concerns because information can be exploited for severe attacks on control systems (ICS-CERT, 2016). The consequences of such data scarcity are so significant that, in some cases, even actors in the process had no access to relevant documentation or were unable to interpret the data.

Second, the loss of knowledge over time has already started during the CIP planning. One finding from the empirical evidence is that information about the outcomes of the process remains classified. Consequently, actors do not know whether prioritised CI objects will receive electricity in a power shortage, and to which extent. Ultimately, this loss of information may trigger problems in subsequent planning and emergency response. The various layers of information scarcity in CIP may thus cause a paradoxical outcome: a planning system created to reduce uncertainty during emergency response may itself create uncertainty in planning. Consequently, research and practice must rely on qualified guessing to analyse possible outcomes and systemic consequences, which hampers also the systematic design of new methodologies (Venable and Baskerville, 2012).

Third, closely interrelated with the former two, the interpretation of processes and methods becomes a multifaceted issue. The analysis indicated that the complexity of the approach and the uncertainty about the adequate level of information security resulted in fragmented knowledge. The revealed lack of systematic institutional knowledge management impeded not only inter-organisational information sharing, but also cumulative knowledge generation and collective learning as well as the dissemination of planning results to interdependent operators of CIP and crisis management. However, the actors mainly used established communication paths and reliable collaboration networks with internal and external actors to discuss their interpretations of the proceedings. The remaining obstacle is the variety of interpretations, which challenge systematic comparative analysis of CIP methodologies, both during research and practice.

Fourth, the transferability and comparability of data emerge therefore as another obstacle. For example, the actors did not really comprehend how the process was conducted the first or even the second time due to the lack of continuity throughout the Swedish approach, which questions the representativeness of the interviews. Rigorous analysis, interpretation, and cross-validation of the collected material were required to distinguish hearsay from concrete experiences (Maxwell, 2010). In comparison, the lack of proper documentation implies that important knowledge disappeared in the *STYREL* process. Moreover, problems in accessing documentation throughout the multi-level planning caused difficulties in validating the proceedings and the outcome for both the researchers in the project and the actors in *STYREL*. Some actors tried to mitigate the problem by assigning one dedicated person to *STYREL*, which unfortunately cannot ensure transferability and comparability of data throughout the entire complex system because no systematic data management exists.

Finally, the methodological obstacles culminate in a lack of collective intelligence. In order to develop new types of mixed methods that combine human interpretation and understanding with artificial reasoning in a reliable manner, the systemic nature of complex societal concerns must be understood (Bentahar and Cameron, 2015; Peeters, et al., 2021). Therefore, the discussed obstacles must be addressed in research and practice. The considerable number of actors in *STYREL* and the extent of the CIP context confer noteworthy complexity to multidisciplinary research projects as well as CIP planning. Hence, to match scientific and practical perspectives, a broader dissemination of results is important for further research and development of reliable methods.

6. Concluding Remarks

This paper highlights some general methodological obstacles to studying and performing CIP in general and CIP governance in particular. First, a lack of access to high-quality data, which emerges from a lack of clear definitions and classification criteria as well from information security concerns in the CIP context, constitutes the greatest obstacle to both research on CIP practice and information sharing among the relevant parties in the area. The second obstacle is the loss of knowledge over time due to unsuccessful knowledge transfer between process activities and iterations. Third, the interpretation of processes and methods causes a range of local proceedings due to adaption to particular circumstances, which reflects a lack of detail and hinders the development of cumulative knowledge in both research and practice. Fourth, this variety of approaches constitutes an obstacle when developing a general understanding of the CIP proceedings, because it hampers the transferability and comparability of data, methodologies and knowledge management. Fifth, the accumulation of obstacles into a

lack of collective intelligence complicates not only the detailed assessment of the decision-making process for the identification and prioritisation of CI and its consequences for society during a power shortage but also the development and application of advanced and integrated methods to facilitate the collaborative work of stakeholders concerned with CIP. This study thus contributes to a deeper understanding of these obstacles that significantly impede research and practice in the context of national and international CIP.

Based on the study's findings, we suggest the following to advance methodologies in complex settings.

First, the results suggest combining centralised with decentralised aspects in the approach for CIP. Although the circumstances of each actor vary, and therefore the proceedings benefit from adequate process adaptation, there are actors whose circumstances vary slightly who could learn from each other. In this context, a central instance could collect related documents and maintain a knowledge basis that consists of concrete models, particular methods and cases, excellent examples, and pitfalls. Such an institutional knowledge base could decrease hearsay and facilitate shared understanding among public and private actors while maintaining a certain security level in information sharing alongside and in between process iterations. Second, in addition to such an institutional knowledge basis, guided decision-making under difficult circumstances and assistance when required could inform the maturation of specific methods and processes for diverse stakeholders in CIP planning and research. Engaging responsible persons from different groups in joint workshops could further assist them with reassessing implicit objectives and underlying assumptions and developing a shared understanding about the societal challenge that CIP intends to solve. Third, to enable all actors in CIP to provide insights, recurring surveys could be a tool to identify weaknesses and sources of knowledge. Therefore, a national organisational structure must complement the current approach. The results of the project underlined the methodological pitfalls of the individual studies and the obstacles that decision-makers face in their planning task. Improving the management of *STYREL* could therefore support dedicated research and vice versa.

Prospects for future research should aim to deepen the understanding of the contribution of each actor to the resulting CIP and societal resilience. In addition, there is a need to address information security concerns jointly to facilitate co-operation among actors and between research and practice. Research and practice need to broaden the perspective on the complex CIP system that not only comprises a considerable number of intertwined technical subsystems, but also human decision-makers and their interactions, (inter-)organisational barriers, interdependencies among CI and environmental constraints, and regulations and policies. Emerging challenges such as climate change, natural hazards, global pandemics, or cyber-attacks necessitate collaborative efforts for approaching, analysing, visualising, and comprehending the interdependencies between CI and the impact of disturbances on society. Such efforts could aid in reducing vulnerabilities and increasing continuity that strengthens the resilience of society. By providing novel empirical evidence from a complex case of national CIP management and highlighting general methodological obstacles for research and practice in this area, this study contributes to the evolution of the new methodological concepts such as collective intelligence.

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