Multi-Level Planning for Enhancing Critical Infrastructure Resilience against Power Shortages—An Analysis of the Swedish System of STYREL

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Citation: Große, C. Multi-Level Planning for Enhancing Critical Infrastructure Resilience against Power Shortages—An Analysis of the Swedish System of STYREL. Infrastructures 2021, 6, 71. https://doi.org/10.3390/infrastructures6050071

Abstract: The protection of infrastructure that is critical to society’s functionality, survival and progression has gained significance because of its large-scale and interdependent nature. This complex system-of-system (SoS) imposes extensive requirements on governance efforts to foster critical infrastructure protection (CIP). This paper uses the kaleidoscope for integrative system analysis (KISA) to investigate a Swedish approach for CIP against power shortages, called STYREL. Based on multiple sources of evidence, such as documents with regard to the case, interviews and a survey with involved experts, the analysis focuses on the system of emergency planning and the usage of the resulting plan. The results deliver insights into the governance of the multi-level planning, including issues regarding policies, the management and operation of STYREL, and accelerating problems in the adaption, emergence and entropy of the SoS, during and between process iterations. Since this large-scale approach largely fails to involve the private sector to enhance the resilience of the society, this proceeding results in uncalculated consequences. In addition, the current design of the approach hampers transparency and evaluation, which poses obstacles to the cultivation of mutual trust, collective learning and a shared understanding as well as proper risk communication with the wider public.

Keywords: critical infrastructure protection; power supply; multi-level planning; complex systems; integrative system analysis; KISA; systemic governance; STYREL

1. Introduction

The protection of infrastructure that is critical to society’s functionality, survival and progression has gained significance for both national security and research because of its large-scale and interdependent nature [1]. The growing interconnectedness of modern societies has increased their dependency on such critical infrastructures as electricity, heating, water supply, healthcare, and information and communication technology. Since the electricity sector is central to other belonging sectors of critical infrastructure [2], further impacts are likely to emerge. For instance, the case of a critical power shortage is likely to yield cascading effects that pose severe consequences for society [3]. Public and private organisations as well as governments have recently recognised the vulnerability that is associated with this dependency, given that exploiting this vulnerability could result in catastrophic consequences [4–6].

A critical infrastructure can be viewed as a complex, socio-technical system-of-systems [7] that imposes extensive requirements on governance efforts to foster critical infrastructure protection (CIP), regardless of whether it involves public organisations, private organisations or both. Critical infrastructure protection can be viewed as a common, societal concern that is located in the field of governance between governmental control and competitive market dynamics as well as the private sphere of citizens [8]. Hence, CIP can be recognised as a purpose that a complex super-system pursues by coalescing forces of its constituting systems to derive benefits, which may include the creation of value for society [9]. The management of society can be viewed as a continuum that extends from...
traditional top-down control to self-organisation and networks, while governance is the common element of this continuum. However, practicing decentralised governance as the opposite approach to centralised government has revealed deficit symptoms, such as dysfunctionality and loss of institutional memory [10], which necessitates a more systemic approach to governance.

The concepts of systems, infrastructure and governance encounter a common challenge: the characterisation of their key elements, namely the components, interactions and environment(s). Therefore, their appearances in the literature cover a broad spectrum of understandings. Briefly summarised, a system is an assemblage of components with properties that, through certain interactions within an environment, fulfil a common (i.e., critical) process that strongly depends on the simultaneous and proper functionality of the majority of components, which can adapt to their conditions [11]. In this form, a system has properties, can exhibit behaviour and may interact with its environment [12]. To maintain the critical process, a system must master entropy, which necessitates a control mechanism, such as artificial reasoning or human decision-making [9]. A system-of-system (SoS) evolves when constituting, independent systems interact to achieve a common purpose, and each system gains some benefit from its participation [13]. Infrastructure is perceived as an always-existing, long-lasting common good that unites material (building) processes and an expression of will (cf. [14]). Nevertheless, even such an SoS requires governance to contend with decaying forces. This systemic governance must be able to ensure accountability and integrity of the governed system—both horizontally alongside processes and vertically through hierarchies while accompanying system dynamics [15]. However, due to the complex character of CIP and the sensitive information involved in planning and operation, the discussion in literature is limited to only a few comprehensive cases of multi-level planning for CIP [9].

This paper aims to contribute novel and comprehensive knowledge for understanding the multi-faceted and complex system of CIP and its governance. Therefore, it concentrates on the practical application of one specific approach against power shortages in the Swedish context called STYREL, and investigates the research question: how does Sweden organise and govern critical infrastructure protection against blackout and what challenges appear in practice?

The STYREL approach represents a novel and unexplored type of policy-making for CIP, as the scientific literature does not discuss similar processes. The Swedish approach offers unique characteristics in its almost non-technical focus and the involvement of an immense number of actors from national, regional and local levels during a long-term, collaborative planning process. This process targets the creation of a policy, which is intended to support planning for and decision-making during a national power shortage situation. The STYREL approach is thus a suitable case of a complex system that concerns policy-making for CIP, and is accordingly relevant well beyond the Swedish context because there is a notable absence of concrete descriptions of such systems, their parts and interrelations as well as of the proceedings during policy-making.

To address this gap, this study utilises the methodical approach of a case study. The investigation is based on an examination of documents that relate to the case, interviews with 66 responsible experts and a survey among all 21 County Administrative Boards (CABs) and 10 power grid operators (PGOs) that are responsible for stabilising the power grid during disturbances. The contribution of this study is threefold. First, it provides an extensive representation of an unexplored case of CIP governance. Second, it offers a new comprehension of practical challenges in CIP due to the complex nature of the system and the entangled processes. Third, it provides empirical evidence that indicates areas for the development of CIP governance practices.

After detailing the methodological proceedings, this paper presents the key findings of the study on the complex Swedish case and discusses their implications for emergency response to protect critical infrastructure and society. A brief conclusion completes the paper.
2. Materials and Methods

The methodical approach of a case study allows this study to investigate a real-world phenomenon of significant complexity while maintaining a holistic perspective [16–19]. Since the use of multiple sources of evidence arguably benefits the overall quality of case study research [16,18], this study incorporated documents with regard to the case, interviews with involved experts and a survey with actors from both public and private organisations. Confidential meeting protocols, field notes, individual experiences and reflections of the involved researcher enriched the material basis [20]. This proceeding allowed for data triangulation [21,22]. Archival records could not be included due to information security concerns.

First, this research investigated publicly available textual material regarding STYREL. The collection mainly consisted of official policies and user instructions, legal regulations, public investigations and reports as well as evaluations of the pilot in 2009 and the first run of STYREL in 2011. Such material included the following sources:

- User instructions and guidelines [23–29].
- Laws and regulations [27,30–39].
- Evaluations at local, regional and national levels [40–48].
- Public crisis management exercises that used the results of STYREL [49,50].
- Future adoption of the concept [51–53].

Second, this study selected three counties out of 21 for conducting interviews; one county includes one of the three major cities, one county includes heavy industry close to the capital and one county represents the rural countryside. A total of 66 responsible individuals from CABs, municipalities and PGOs participated in the interviews. The sample involved all responsible officials from the CABs and all 49 municipalities in the three counties as well as 14 representatives from local, regional and national PGOs. The size and structure variation in the regions allowed for a broad spectrum of local experiences, requirements and constraints, which imparted appropriate information power in the sample [54,55] and supported a thick description of the STYREL process and the executing system.

Material was collected from semi-structured face-to-face interviews and one interview that was conducted via telephone. A guide with open-ended questions was employed to ensure a similar structure across interviews and allow participants to report individual experiences and perceptions. Follow-up questions were posed to achieve more clarity and richness of detail. The interviews lasted for one hour on average and were recorded and transcribed. The proceedings further entailed anonymising and aggregating the material and results to secure sensible information with regard to both privacy and confidentiality. Moreover, participants were always permitted to discuss issues without being recorded. In such circumstances, the researcher’s notes completed the data collection.

The subsequent in-depth content analysis of the interview transcriptions produced a deeper understanding of nuances in meaning and verbal expressions by replaying the recordings alongside the analysis. The analysis of the transcriptions followed an iterative process. First, the transcriptions and recordings of the county representing the rural countryside were analysed. Departing from the questionnaire, the results to the main categories were highlighted manually in the material. After gaining an initial understanding of specific issues and relevant examples of proceedings, detailed categorising and coding was performed with the aid of AtlasTi software to facilitate the analysis of further interviews during the course of the study. This analysis applied the kaleidoscope for integrative system analysis (KISA) to facilitate the examination of the Swedish case from a holistic perspective [56]. This conceptual frame includes four perspectives: system, infrastructure, process and governance. These four recursive perspectives are based on three layers that mirror the ability of the perspectives to adjust the special focus on the micro, meso or macro level of a system of interest. The analysis of the other two countries both broadened and deepened the understanding of the content until saturation was reached. Furthermore, the data analysis applied a hermeneutic approach to policies and interviews, which necessi-
tated deliberate, reflected subjectivity of the analyst to interpret data and results that could yield novel insights [57,58].

Third, throughout the study, the findings from the textual material and interviews informed subsequent activities, such as the survey. To broaden the view of particular issues, the survey encompassed all 21 counties in the first step and, in the second step, considered the 10 PGOs that stabilise the power grid during the initial phase of a power shortage. Since the regional level maintains a central role as coordinator in the approach, the survey focused on the perceptions of cooperation and decision-making at the regional level. The evidence from the interviews with the three CABs informed the development of the 34 survey questions about the respondents’ perceptions of the effectiveness and efficiency of STYREL in general and the proceedings of the planning process within their respective areas of responsibility in particular. Although the majority of the 25 respondents shared their perceptions in the general part of the survey, the rate decreased to around half of the respondents when addressing knowledge of the concrete proceedings of the respective actor. The overall frequency of answers to the survey questions was 63.1%. The answers to the remaining questions were ‘do not know (N/A)’ or even omitted in some cases.

This survey is an example of a small-n study [59]. It focuses on the proceedings in the STYREL process, which limits the number of possible observations. Therefore, it is important to be careful in the conclusions that are based on the interviews and the survey. This study has no ambitions to draw general conclusions about the national CIP system or its parts but to broaden the view of particular issues in the proceedings between actors in this multi-level planning.

The analysis of the data from these multiple sources of evidence utilised the KISA to categorise the material alongside the four perspectives: system, infrastructure, process and governance.

1. **System** embraces concepts with regard to various types of system, such as societal, socio-technical and technical. This perspective concerns a particular snapshot of a system, which captures a certain state at a particular moment in time.
2. **Infrastructure** regards the conglomerate of fixed assets, processes and expressions of will that is (or can become) critical if the survival, well-being and progress of a society depend on its maintained functionality.
3. **Process** considers the key process(es) that a system of interest performs. Thus, its contemplations include related information, process objects as materials and activities that are performed by persons, tools and technologies.
4. **Governance** focuses on concepts and activities with respect to operation, management and politics/policies, which occur in not only public contexts but also non-governmental, public-private or private organisations.

The KISA guides the exploration of the complex case of CIP to acquire beneficial, multi-faceted knowledge and to develop a multi-perspective understanding. The following section pursues the first research question and presents results from the analysis of the SoS for CIP in Swedish practice in detail.

### 3. Findings from the Swedish Case of STYREL

The subsequent section details the Swedish approach to CIP against power shortages, called STYREL. First, it elaborates on the SoS that surrounds and executes the planning process that Figure 1 depicts. To this end, it focuses on the particular components, such as the actors in the system, their interactions during the planning, and considerations regarding the system environment. Then, it targets the usage and implementation of the resulting plan for CIP in Sweden. Finally, it delivers insights into the governance of the multi-level planning, including issues regarding policies, the management and operation of STYREL, and accelerating problems in the adaption, emergence and entropy of the SoS during and between process iterations.
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Figure 1. The reference process of STYREL (MFK is the Swedish acronym for manual load shedding: manuell förbrukningsfrånkoppling).

3.1. The System-of-Systems Associated with STYREL

The key actors and stakeholders in the Swedish case can be viewed not only as independent systems within a broader CIP context but also as part of their respective milieus. Within these environments, the actors—as components of the SoS—maintain various interactions. Table 1 details the involved actors and their areas of responsibility in society and STYREL.

Imbalances of power production and consumption require control activities to maintain the power grid in a stable state. This balancing can lead to power outages for some consumers. A swift response to certain circumstances can be imperative to protect society from negative consequences. The Swedish approach pre-emptively identifies critical power consumers and their importance for society. For this purpose, it uses the eight-point scale in Table 2 [31]. Apart from this scale, no further decision aid is available.

The Swedish Energy Agency (EA) provides the official policy that outlines STYREL as follows [26]. First, at the national level, four national authorities (see I to IV in Table 1) commence the planning process. The EA (III), as the government-entrusted actor with overall responsibility for the process, informs other national agencies (V) and all CABs (VI). Many national agencies are requested to document the critical infrastructure for which they are responsible. This inventory identifies key power consumers and prioritises their importance for society according to the scale in Table 2. The national agencies then distribute a separate list of their inventory to the CAB in each county in which the critical infrastructure is physically located [26].
Table 1. Actors in the Swedish planning approach—STYREL.

| No | Actor                                           | Area of Responsibility                                                                 |
|----|-------------------------------------------------|----------------------------------------------------------------------------------------|
| I  | Swedish Civil Contingencies Agency              | • National prevention, contingency and crisis management                                 |
|    |                                                 | • STYREL—process development                                                             |
| II | Swedish Energy Market Inspectorate             | • Control of the Swedish energy market, pricing and policies                              |
|    |                                                 | • STYREL—process development                                                             |
| III| Swedish Energy Agency                          | • Reliable and sustainable energy supply                                                |
|    |                                                 | • STYREL—process development, initiation of process execution (national), direction and guidance |
| IV | National PGO                                   | • Maintenance of the national power grid and power supply                                |
|    |                                                 | • STYREL—process development, supervision of planning for and execution of manual load shedding (which subsequently implements the results of STYREL) |
| V  | National Agencies (ca. 100 out of 458)          | • Various tasks affecting societal security                                              |
|    |                                                 | • STYREL—identification and prioritisation of critical infrastructure that the particular agency operates, distribution of planning documents to the CABs where objects are physically located |
| VI | County Administrative Boards (all 21)          | • Representing the government at the regional level                                      |
|    |                                                 | • STYREL—process execution (regional), distribution and compilation of planning documents, direction and guidance |
| VII| Municipalities (all 290)                       | • Representing society and acting locally                                                |
|    |                                                 | • STYREL—process execution (local), identification of critical infrastructure, collaboration with PGO (operating locally) and public and private operators of critical infrastructure (located locally), prioritisation of assets and controllable power lines |
| VIII| Power Grid Operators (all, ca. 160)            | • Grid maintenance and power supply at the regional/local level                          |
|    |                                                 | • STYREL—assisting municipalities with information on how critical infrastructure relates to power lines; planning for manual load shedding |

Table 2. Classification scheme of critical infrastructure [31].

| Class | Score | Description                                                                 |
|-------|-------|------------------------------------------------------------------------------|
| 1     | 7     | Power consumers that have a large impact on life and health in a short time frame (hours) |
| 2     | 6     | Power consumers that have a large impact on vital societal functions in a short time frame (hours) |
| 3     | 5     | Power consumers that have a large impact on life and health in a longer time frame (days) |
| 4     | 4     | Power consumers that have a large impact on vital societal functions in a longer time frame (days) |
| 5     | 3     | Power consumers that represent large economic values                          |
| 6     | 2     | Power consumers with major importance for the environment                      |
| 7     | 1     | Power consumers with importance for societal and cultural values               |
| 8     | 0     | All other power consumers                                                     |

Second, the CABs initiate the execution of the planning at the regional level and provide information about the proceedings to their municipalities. In addition, each CAB processes the inventories of the national agencies and prepares a particular selection for each municipality (VII) [26].

Third, at the local level, municipalities are encouraged to identify power consumers that are vital for the local society. Responsible individuals at municipalities prioritise these key consumers by applying the aforementioned scale. With respect to the limitations for controlling electrical power, municipalities must further observe technical feasibility.
Therefore, local PGOs (VIII) provide information about the relation of the power consumers to controllable power lines at the request of the municipalities. With this information, various consumers—each with a score based on its 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 this aggregation, municipalities must 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 their responsible CAB [26].

Once the ranking list returns to the regional level, the responsible CAB then prepares a compiled ranking, which involves all lists from their municipalities by using another spreadsheet that automatically applies another additive aggregation. In co-operation with municipalities and neighbouring CABs, each CAB specifically considers power lines that cross local and regional borders so that the resulting compilation is adequately attentive to the initial classification of key consumers. Each CAB then conveys the completed compilation to the Swedish national PGO (IV) and the respective parts of the ranking list to the interrelated local PGOs [26].

This large-scale SoS, which performs the planning for CIP with regard to the power supply (see Table 1), is embedded within a shared environment of societal responsibility. Each of the components of this SoS is simultaneously a component of another SoS as well. Therefore, the STYREL planning is only a relatively small part of the total workload for each actor in its daily business, and the particular environment of each actor dominates the interpretation of its role in the planning. As the results of this case study repeatedly illustrate, the scant attention to STYREL between the process iterations affected both the actors’ awareness of the contextual frame and their interpretation of particular roles in this SoS. In addition, the commitment of actors and the knowledge and experience of this planning for CIP gradually diminished over time.

As part of the Swedish system for crisis management, the regional body operates as a co-ordinator that organises co-operation and interaction among actors from the public and private sectors. The CABs bear a double burden in STYREL as participants in the process and as regional co-ordinators. During the execution of the planning, CABs occupy a central role as intermediates between the national, regional and local levels [60]. According to the reference process, the CAB’s role is directed both from the top down and from the bottom up; however, the latter is incomplete because the national level lacks co-ordination. Regarding process execution, this case study reveals that 58.3% of the responsible persons at the CABs had never participated in STYREL before, while 25% had participated once and 16.7% had taken part twice. The evident lack of knowledge is likely to impact their ability to co-ordinate the proceedings and process information. In addition, between the first and second process iterations, the role of the CABs changed. In the first iteration, the CABs had access to detailed information to participate more actively in assessing and balancing the priorities of the critical infrastructure assets at the county level. In the second, the CABs received limited information to compile the results from the municipalities. As this study highlights, this change influences the SoS and the relevance of the planning results for CIP.

Such blind spots in the design, execution and evolvement of the Swedish multi-level planning system challenge CIP and its governance [61]. Missing feedback, collaboration and knowledge are recurring issues, among others, which relate to staff changes at the actors. For example, slightly more than 40% of the officials at the municipalities and the PGOs who participated in the survey had no experience with STYREL. Since the reference process only poorly specifies concrete proceedings, many actors found themselves in a situation of conflict to serve the purposes of two or more SoS to which they belonged. At the level of an individual decision-maker who acts on behalf of the key actors in the SoS, this conflict led to adaption, which reflects resignation, fading commitment or learning from hearsay. As such adaptions cumulate over time, the Swedish SoS that identifies and prioritises critical infrastructure is likely to present an emergent behaviour during the next iteration of STYREL. Effects can emerge as, for example, changes in the participation of
particular actors, the amount of provided information or the dedication of resources. The case study indicates that contending with the complexity of the SoS and the process creates a substantial level of entropy that compromises the efficiency of the system. In addition, an increase in entropy over time further reduces the effectiveness of the process and the efficacy of its results for CIP.

3.2. Critical Infrastructure Protection with the Aid of STYREL

One objective of STYREL is to ‘alleviate consequences for society that emerge when manual load shedding must be executed’ [26]. Another objective of the planning process is to achieve a plan that ‘PGOs can use as basis for their response planning’ [26]. The EA website communicates a third objective: ‘to prepare data to be able to prioritise societal important power consumers in the case of manual load shedding’ [62]. These objectives convey the intended use of the STYREL plan as a means for subsequent planning for CIP, including both the Swedish crisis management system, which addresses the consequences of disturbances in societal functions, and the electrical power system, which is of vital importance for other critical infrastructure. While the former usage is not clearly defined, the maintenance of power grid stability is at the forefront of the Swedish approach. The official handbook mentions this utilisation of the results for the planning of load shedding as a final step in STYREL (see Figure 1). However, the findings demonstrate that the PGOs instead viewed this step as a subsequent planning that involves the results of STYREL where it appears possible. A similar view emerged regarding the effectuation of the results of both plantings during a power shortage or outage.

Since CIP for the power supply is the central concern of STYREL, the PGOs are main users of the results. At the next level of planning concerning measures for ensuring stability of the power transmission system, all PGOs are legally obligated to use the allocated ranking lists to plan their response in the event of a power shortage. Whereas the national PGO only stores this information, planning for load shedding at the local level allows for maximum adherence to the ranking list of STYREL during an emergency.

Similarly to other power grids, the Swedish grid must manage the grid frequency to prevent blackouts (see [63]). When the frequency is low, and no reserve can be activated or imported, load shedding is a measure to stabilise the power grid. The planning for load shedding is twofold.

The first part concerns a plan for manual disconnection of demanded power. In Sweden, all PGOs are legally obligated to independently perform this planning, which must permit each operator to disconnect at least 50% of the actual load. Since the current load can vary considerably during a particular period based on, for example, the season, weather conditions or time of day, the planning of PGOs departs from the maximum load that occurred in the last year. The resulting plan for disconnecting power consumption involves the results of STYREL to ensure that the critical infrastructure receives electricity that is as undisturbed as possible.

The second part addresses a plan for automatic disconnection of demand. This planning, which only PGOs that are directly connected to the national grid must perform in the southern part of Sweden, considers at least 30% of the actual load for sites in the southern part of Sweden, while the manual and automatic disconnection schemes may overlap by only one-fifth. The latter planning also involves larger boilers and heating pumps, which is similar to that of continental Europe [33].

Manual load shedding occurs in situations in which the electricity demand slowly increases until the production and transmission are finally unable to fulfil the demand. In contrast, automatic load shedding takes place mainly in situations in which a sudden imbalance emerges due to, for example, a failure in a power plant. In general, the PGOs strive to plan for such measures with minimal negative societal consequences. However, the study of STYREL reveals several obstacles for the PGOs with regard to the usage of the received information, such as the completeness and level of detail in the documents and insufficient knowledge of the planning for load shedding at other PGOs.
The first obstacle concerns the completeness of the critical infrastructure ranking. During the third step of the STYREL process at the local level, PGOs receive detailed information about the identified critical consumers. The interviews reveal that municipalities maintain closer interaction with smaller, locally based PGOs than with larger providers who operate many local grids. In some cases, the representative of a locally based PGO was completely involved in the identification and prioritisation of critical infrastructure, which may influence the completeness and usability of the process outcomes. In contrast, the three larger PGOs operate local grids in up to 120 municipalities. The sheer amount of data that these companies had to process poses an obstacle to closer collaboration. In addition, the recent STYREL planning hardly involved larger parts of civic society and neither non-governmental nor private organisations. This study reveals that such proceeding stipulates a workload that surpassed the capabilities of the municipalities. This absence implies that the majority of privately operated critical infrastructure is not represented in the plan that the PGOs applied in their planning of load shedding.

The second obstacle relates to the level of detail in the received documents. During the execution of STYREL, the PGOs receive detailed information about the critical infrastructure assets and provide information about the relation of critical infrastructure assets to power lines. However, in the final ranking of power lines that the PGOs ultimately receives, the asset information is omitted. The ranking thus contains a level of specificity that precludes a detailed assessment. A consequence is that the PGOs have difficulties finding appropriate non-prioritised power lines to install automatic load shedding without affecting the critical infrastructure. In addition, the power grid is constantly under development to not only adapt to a growing demand for electricity but also maintain the physical transmission system. Therefore, changes in the grid’s structure can cause the power supply to a particular power consumer to be realised via another power line than was assigned to this consumer during step three of STYREL. Because of such changes over time and the lack of detail in the final documents, the PGOs cannot assure the intended implementation in the regular planning of load shedding, especially between iterations of the STYREL process.

The third obstacle relates to the absence of knowledge of the load-shedding plans at other PGOs. The poor alignment of these plans implies that the PGOs can handle their own grids but otherwise have no knowledge of the consequences of their measures for sub-grids. This obstacle can hamper the fulfilment of the planning of load shedding, and it is likely to have an impact on critical infrastructure at the local level in the case of a power shortage.

These three obstacles exemplify the interdependencies between the system of STYREL, its reference process, the decision-making in its execution, the subsequent implementation of results in further planning and the effects for critical infrastructure during effectuation in a crisis situation.

When a power shortage occurs, the national PGO is primarily responsible for manual load shedding in Sweden. Apart from the national PGO, nine out of all PGOs in Sweden are delegated certain responsibilities during the initial phase of managing power supply disturbances. These PGOs maintain preconditions that allow them at any time—by order of the national PGO—to reduce the power consumption in accordance with a demanded volume. This consumption reduction shall be effectuated within 15 minutes of receiving the order [46,47], and it should adhere to the prioritisation of the STYREL process as much as possible. The case study reveals several difficulties due to the brevity of this period. For example, severe circumstances can force regional PGOs to reduce the demand at the regional level without knowing which critical infrastructure such a cut will affect. STYREL intends to mitigate this problem, but very few PGOs are currently able to effectuate manual load shedding at the local level within this time frame. The mentioned absence of alignment during the planning of load shedding between regional and local PGOs still hampers a more precise effectuation.

Even in cases in which these PGOs are able to effectuate manual load shedding while fully complying with the received STYREL plans, the lack of details in these documents in
combination with the grid development over time endangers the reliable power supply to societally important consumers. Since the PGOs have no means of tracing such changes in advance, the consequences are first observable during emergencies, such as that of a national power shortage.

Another fact aggravates the risk and reduces STYREL’s efficacy: not all affected stakeholders are included in the process (e.g., the private sector is not meaningfully involved, and the civic society is practically unrepresented). On the one hand, this exclusion implies that a considerable portion of the privately operated infrastructure can be affected. STYREL fails to analyse the consequences of such outages, which demonstrate the conflicts of the system with the intended objectives. On the other hand, it can further indicate that a substantial part of the society may experience a blackout without appropriate preparation, which requires further consideration by the crisis management system.

However, this study evidenced that a majority of the public actors treat STYREL largely separately for several reasons. One issue that recurred during several studies on the Swedish case is the lack of feedback. For example, municipalities emphasised that they require more feedback during and after the process to successfully integrate STYREL into local risk assessments and emergency response planning. The CABS noted that the removal of information during the process rendered it impossible for them to evaluate the received documents and the extent to which initial preferences for national or regional critical infrastructure were preserved during the planning. This information scarcity hampers the integration of STYREL into other efforts of CIP and crisis management. Since the process sequentially removes information, the PGOs receive a plan that significantly restricts their ability to ensure a power supply to societally important power consumers during disturbances. Moreover, the only situation in which adherence to STYREL is legally obliged is when the national PGO identifies a national power shortage situation and decides that co-ordinated manual load shedding must be effectuated. This limited focus is likely to impact the implementation of the STYREL results in other situations, for example, during restoration after a major blackout or for the planning of regular power grid maintenance.

Although this case study indicates side effects for local risk assessments, CIP and crisis management, tracing the potential of STYREL for CIP illuminates conflicts with the objectives as stated at the beginning of this section. Although the level of fulfilment remains questionable, the approach mostly contributes to the second objective. The first is not evaluable in the current setting; it signifies a general vision for CIP as opposed to an objective for STYREL. The third is hardly possible to fulfil in view of the changes to information proceedings between the first and second iterations.

3.3. Governance of STYREL in the Context of Swedish CIP

The Swedish government entrusted the EA with establishing emergency response to ensure the power supply. After a pre-study [64], the STYREL approach began development in 2004. A pilot was carried out in 2009, and the first national execution in 2010/2011 completed its implementation [47]. Since the planning stipulates new iterations at four-year intervals, the second execution of the process was performed in 2014/2015. The schedule for the third iteration collided with elections and other tasks at the municipalities, such as risk and vulnerability analyses, so this iteration was postponed for one year, and the timeframe of the process was extended. It was intended to run between 2019 and 2021. Due to the ongoing COVID-19 pandemic, the process is now adjourned [65].

Against the background of national regulations, the EA possesses overall responsibility for the governance of STYREL, including its process, results and development. However, the approach delegates responsibility among the actors of the SoS as is apparent from the national regulation and Table 1. During the multi-agency process, the EA provides the following support:

- A handbook that describes the national policy for the approach;
- A user guideline that dictates the main functions of the planning spreadsheets and which actor should fill in which kind of data;
• Preparatory meetings with general information for key actors;
• Short movies that exemplify the usage of the spreadsheets.

Apart from these contributions in the initial phase of the process iteration, the EA performs neither system or process management and leadership activities nor co-ordination at the national level of the process.

The CABs are responsible for co-ordinating work with the system at the regional level. This role of the CABs proceeds alongside the major part of the planning process until the distribution of the results to the PGOs. Each CAB is expected to guide and mediate STYREL among the municipalities, though the policy allows each CAB to determine the actual structure and organisation of the regional proceedings. As mentioned, more than half of the responsible persons at the CABs have not previously participated in STYREL, which suggests that knowledge within the system is stunted and that the CABs struggle within this role. Criticism focused on the design of the reference process and process execution as well as on the limits to the usefulness of the resulting plans. During the case study, the evidence from the empirical investigation was dominated by several issues, such as an absence of feedback, the interpretation and application of the classification scheme in Table 2, the extent and quality of the resulting plan, the handling of information during the process and a feeling of insufficient support during and between the planning iterations. Although the EA encourages municipalities to anchor the process at the top-level management, officials at municipalities reported difficulties with local governance of the process. Similar to the CABs at the regional level, the municipalities must adapt the general policy to the local conditions to create a local setting and establish sufficient information paths. The STYREL handbook recommends involving private organisations, as these organisations operate a substantial part of critical infrastructure; however, the concrete proceedings are otherwise left to each public actor. As the interviewees reported, dedicated resources and geographical conditions are examples of the constraints that affected the concrete form of this time-consuming process. In consequence, many municipalities were challenged by the involvement of the private sector as well as the integration of STYREL into other local crisis preparation. In addition, the classification scheme was subject to extensive discussion and diverse interpretations and adaptions. For example, some actors developed their own lists of critical infrastructure assets that fit into each class or applied further sub-criteria, such as the turnover and number of employees of a classified operator of critical infrastructure or risk-enhancing geographical issues.

The findings demonstrate that the main role of PGOs is that of an information provider in STYREL. In this role, many of them perceived drastic differences among municipalities regarding the STYREL and prioritisation of critical infrastructure. This experience in combination with the information scarcity in the final documents affected the application of the resulting plan. Although the regional PGOs have established contacts with their subcontractors in regard to the power supply, the planning for load shedding and grid maintenance is performed by each PGO independently. Each PGO is legally obligated to plan for load shedding and to inform the national PGO and related CABs when it is due. However, the study findings reflect both a low rate of ready messages and poor alignment of the subsequent planning for load shedding.

In general, STYREL lacks a proper means of assessing and comparing processed information, which in turn, hampers future improvement. The perceived lack of feedback in combination with staff turnover during and between this large-scale and long-term planning aggravates the problem and causes adaption, emergence and entropy in the multi-level SoS. Moreover, the absence of criteria for assessment, selection, success, quality, information security and performance complicates the evaluation of the entire process and its results. Although the few evaluations of the process development have already emphasised some of these issues, only slight changes have been made to the following policies. In addition, documentation of this improvement process or evaluations of the second round is absent, which suggests that such documents either do not exist, are classified or have not had their information released by the owner. None of the co-ordinating organisations
or any central instance collects any documentation or evaluation from the participating actors. The regulation explicitly refers to the EA, the MSB and the national PGO as key actors that are responsible for further development of the Swedish approach. However, the highly limited dedication of resources, the staff turnover and the weak system design also challenge the national actors. These issues obstruct not only improvements at the national level of the decision-making process but also further development of the reference process and the alignment of strategic objectives among the actors in society.

Today, the approach is not well-integrated; therefore, many of the key actors regret the absence of a holistic, integrated view of SWYRE and envision that integration and transition of the planning process is a crucial pay-off to the Swedish crisis management system at subsequent planning levels, such as those for preparedness and contingency planning.

The findings from studying the Swedish case highlight the need for thorough consideration of the various interests that are involved in such a complex system of national multi-level planning. The analysis further highlights ambiguity in several steps of the process; for example, the designation of information paths, expected efforts and responsibilities remains unclear. The results indicate that different interpretations of vague descriptions and implicit objectives prompt different proceedings. Thus, uncovering tacit content and its significance can assist with converting objectives, which can in turn facilitate the development of the SoS. Because of the number of actors and stakeholders in the Swedish CIP, strategic objectives are numerous, highly diverse and will occur simultaneously. Besides exploring the system conditions and strategic objectives, the empirical evidence encourages a thorough analysis of the challenges for governance that emerge from bundles of strategic objectives and their influence on governance activities as well as further adaption of the SoS.

4. Discussion

4.1. Implications for CIP in Sweden and beyond

This study obtained results from a Swedish approach for CIP that seeks to manage the societal consequences of power shortages by identifying and prioritising critical infrastructure. The results reveal several stakeholder groups that such crises would affect. However, many local implementations of the approach ignore the majority of society. On the one hand, many adaptions of the proposed policy-making process almost exclusively consider infrastructure and interrelated services that are municipally operated. Although these assets and services constitute a relevant part of critical infrastructure, this limitation of the approach disregards the mostly privately operated systems and processes that produce and distribute a flow of essential goods and services [9]. In addition, it overlooks the capability and capacity of citizens to cope with power shortages [66], which leads to misjudgements about their consequences. On the other hand, participation in the policy-making process is similarly incomplete. The process basically involves national, regional and local authorities as decision-makers as well as PGOs as advisers and final receivers of the policy. Although the approach allows for individual settings within each actor’s area of responsibility, this study identified only a few implementations in which further stakeholders were included or the local PGO was part of the entire process. Moreover, only a highly limited group of stakeholders was involved in the creation of the governance approach. The results of this study indicate that even less participation is occurring in further development of the governance approach.

One explanation for these limitations interrelates with the structure of the problem and the solution approach. This study demonstrates that the multi-level character of the problem challenged the structure of the approach. For example, the local level was expected to not only assess the local circumstances but also include the regional and national perspectives, which often exceeded local capabilities. Since the approach deliberately limits the information exchange between the local and regional levels, the latter had to contend with an information scarcity that rendered it practically impossible to assess local, regional or national perspectives. Moreover, the implementation underrepresents the national
perspective, which also previous research has emphasised [67]. Although the Swedish approach seems to transform the top-down hierarchy of traditional government into a flexible network structure, it fails to adapt to the multi-level character of the problem. Such a character is evident from the multiple levels of the power transmission network and the infrastructure and services, which produce and provide services that may be of interest for not only one local community but also a regional, national or global society. In addition, the Swedish approach does not stipulate feedback structures with regard to the results of the identification and prioritisation or further development of the process and the interrelated SoS of CIP. This study illustrates that such absence of feedback affects the actors in the system, which in turn induces individual adaption and emergent system behaviour [11,61].

The accompanying means, which are tightly intertwined with the structure of the governing system and its processes for facilitating CIP, have an effect on the outcomes. The results highlight a need for paying particular attention to the tools and methods for assessing infrastructure and services to identify and prioritise the critical portion of them in local, regional and national contexts as well as the timeframe of a possible crisis. First, such an assessment involves a vast amount of partly sensitive data, which necessitate systematic data management that includes proper levels of information security. Second, the collection and analysis of relevant data require not only a clarification of data sources, methods and the scope for interpretations but also the dedication of resources and tools as well as a constructive dialogue about the implications of the particular outcomes for society and interrelated risk and crisis management.

This study particularly stresses the importance of integrating the planning process into the larger context of national emergency response planning and crisis management to account for interdependencies [1]. For example, although the electricity sector is acknowledged as central to the critical infrastructure [2], some critical services also depend on an electricity-independent infrastructure, which is a priori excluded from the Swedish approach. If an application of the final plan in local risk analysis and crisis management is not properly considered, it could insinuate that such dependency does not exist. While many actors in the Swedish case could benefit from the integration of the planning into their day-to-day work, only a few have made progress since the governance approach neglects to explicitly address and properly support such integration.

Finally, two issues emerge from the experiences with the COVID-19 pandemic. First, it has become apparent that the proper functionality of critical infrastructure in many cases depends on the availability of the operative personnel, recently acknowledged as system-relevant staff. Thus, mature continuity plans that include staffing have gained importance. Second, the workload of several actors in the investigated SoS increased significantly, which motivated a two-year postponement. In addition to a previous justification, this means that the stipulated 4-year interval between the planning rounds now has developed to a 7-year interval, which in turn, very possibly aggravates the issues that this study has outlined.

4.2. Indications for Future Research

The research for this paper has been subject to several limitations. In particular, the multi-disciplinary and complex nature of the investigated approach for CIP with regard to the power supply provides a wide range of promising prospects for future research beyond the scope of this study. Such efforts can contribute to the multi-disciplinary canon of theories and concepts, methods and specific cases.

One course of research could link to the case study. Since this study is partly based on the retrospective views of the interviewees, a replication could examine the concrete proceedings alongside the decision-making process for different stakeholders. In addition, such investigation could analyse the current state of the SoS and thereby reveal the effect of time on the state and relevance of the approach. An application of complementary methods could further improve the comprehensiveness of the representation, and research on similar cases in other sectors of CIP or other countries can broaden understandings of the scope and the context of this concern.
Additional research could concentrate on the development of methods and tools to facilitate both research and practice in the context of CIP. The research for this study had to contend with information scarcity mainly due to information security concerns and a low level of trust among the actors in the CIP context. Future development of methods and tools would require improved collaboration between research and practice, even across research disciplines and critical infrastructure sectors. For example, the additive approach, which STYREL applies for calculating a local ranking of power lines upon the classification of critical assets on each line, needs further improvement. Developments could address the establishment of a baseline and specific thresholds since they are absent in the current setting (apart from the scheme in Table 2). The quantitative approach must also advance because the simple addition method can imply that a high-priority object, which may also be of regional or national interest, can fall in the regional ranking if there is a low number of other prioritised objects on that line.

Moreover, the study characterises CIP as a common societal concern. This view implies a variety of perceptions of the value of infrastructure and services for affected stakeholders in decision-making. For many participants in the study, ethical questions about the identification and prioritisation of critical infrastructure were matters of concern. Therefore, future research could revolve around aspects of equality and solidarity, self-responsibility and capability of the ideal citizen, uniformity and group behaviour in policy networks as well as technical challenges due to an increase in renewable energy.

As the case study has indicated, the Swedish approach does not yet comprehensively include all strategic objectives which the systemic parameters of the SoS pose for CIP; therefore, more effort is needed to identify and involve hidden stakeholders and objectives to improve resilience in society. Additionally, a better alignment of the objectives within the multi-level planning system of CIP is required to address processes and structures at several levels of concern in society and mediate among them [68]. However, this requires both a well thought-out and values-based overall vision in multi-level planning and an appropriate balance among the long-term and short-term goals at the strategic, tactic and operational levels [69,70]. Thus, the challenge is still to establish the balance between control and flexibility, complexity and capability to act, dispute and dialogue, participation and self-indulgent publics, common structure and local variety, and systematic and ad hoc proceedings.

5. Conclusions

This study investigated the inter-organisational co-operation during emergency response planning for power shortages and the application of the preparatory plan for CIP in Sweden. The paper demonstrated that the Swedish approach encounters several challenges. Evidence from public policies, interviews and a survey with actors from both public and private organisations highlights issues in the design, execution and evolvement of the Swedish multi-level planning for CIP. The approach engages a large number of actors, such as all municipalities, CABs and PGOs as well as national agencies, to perform the identification and prioritisation of electricity-dependent critical infrastructure, which subsequently constitutes the foundation on which PGOs can plan for, and ultimately execute, load shedding in the event of a power shortage. One of the challenges that this study of the Swedish case discovered is the difficulty of estimating the intended benefit for the actors in the SoS that perform the planning and the society that STYREL affects. Examples of the reasons for this difficulty include the following:

- A lack of knowledge about the specific needs of the constituting systems, the individuals who are entrusted with decision-making, the infrastructure that the protection concerns and the society that it serves;
- The absence of consequence analyses, including relevant measures, to evaluate the impact of the decisions that are made in each process step;
- Weak integration into crisis management for further usage of the collected information about the infrastructure and the ultimately produced plan.
A second challenge is to coalesce forces in and around the SoS for CIP to maintain societal security and provide a basis for sustainable development. In the current approach, a subsequent actor in the process must rely on the expertise and dedication of the preceding actor. For example, CABs depend on the commitment of the municipalities and their assessment of infrastructure; likewise, PGOs rely on the commitment of both and their understanding of the importance of infrastructure assets and proper collaboration. Moreover, the actors lack measures to evaluate the quality of information that the system processes. Information flaws and impersonal interactions intensified individual prejudices rather than alleviating them, which also reflects the variation in understandings and lack of consensus within the SoS.

In accordance with the question of how to organise and govern CIP, one major insight from the Swedish case is that many local implementations overlook the majority of society because of several constraints, such as the limited participation of relevant stakeholders in the process and assessments that almost exclusively target officially operated facilities. Another insight is that the focus on end-nodes of the electrical grid and local power lines pose difficulties for integrating local, regional and national levels of concern, including interdependencies among infrastructure and services, into the assessment and decision-making. The sequential order and information scarcity in the policy-making process and the SoS of CIP leads to individual adaption and emergent system behaviour. A third insight concerns the sensitivity of handled information. The Swedish approach deliberately distributes the responsibility for managing information security to each actor, which significantly complicates the information exchange within the SoS. Knowledge management is almost absent, and regular evaluation is neglected. Thus, a rather collective approach of mutual information and knowledge exchange would be necessary to enhance CIP, which, however, often conflicts with information security concerns in this area. In addition, a lack of transparency and evaluation poses obstacles to the cultivation of mutual trust, collective learning and a shared understanding as well as proper risk communication with the wider public.

**Funding:** This research was funded by the Swedish Energy Agency, grant number 40307-1.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Conflicts of Interest:** The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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