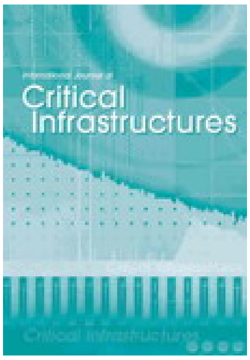

International Journal of Critical Infrastructures

ISSN online: 1741-8038 - ISSN print: 1475-3219
https://www.inderscience.com/ijcis

Information-flawing filters in critical infrastructure protection: the deficient information basis in a Swedish approach

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DOI: 10.1504/IJCIS.2023.10038635

Article History:

Received:	08 January 2021
Accepted:	05 February 2021
Published online:	17 February 2023

Information-flawing filters in critical infrastructure protection: the deficient information basis in a Swedish approach

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Abstract: Various societal functions, such as healthcare, freight transports, water supplies and electricity, ensure the daily life, endurance and progress of modern societies. The protection of such critical functions requires comprehensive information processing. Based on evidence from documents on the Swedish planning process *Styrel* and interviews with entrusted decision-makers at county administrative boards, municipalities and power grid operators, this study aims to crystallise information pathways and flaws to highlight information filtration and alteration. Analyses of the material reveal a set of information-flawing filters, such as information withholding or loss when sharing, information scarcity in criticality assessments and ad-hoc information creation due to scarcity. Because of these filters, the Swedish process causes an altering of information that affects the quality of decisions and the emergency response plan that relies on them. Thus, this study indicates deficiencies that relate to information sharing, information security and decision-making that poses risks to citizens and businesses.

Keywords: critical infrastructure protection; CIP; societal security; information management; decision analysis; multi-level planning; public private policy network; filters; Swedish policy; information pathways; information sharing; security; decision-making.

Reference to this paper should be made as follows: Große, C., Larsson, A. and Björkqvist, O. (2023) 'Information-flawing filters in critical infrastructure protection: the deficient information basis in a Swedish approach', *Int. J. Critical Infrastructures*, Vol. 19, No. 1, pp.40–57.

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1 Introduction

The daily life, endurance and progress of developed societies depends on a number of critical societal functions which include healthcare, freight transports, water supplies and electricity. Together, these functions comprise *critical infrastructure (CI)*. To protect such infrastructure and maintain it during disturbances, such as electrical power failures, policy-making on national emergency response requires comprehensive information processing. This information processing encompasses the procurement, transition and utilisation of the information and its contents. The quality of the processed information is constantly dependent on various requirements, such as the needs of involved decision-makers, the demands of national and international information security policies and the expectations of the diverse actors who are concerned with critical infrastructure protection (CIP) and crisis management. CIP involves sensitive information about CI and protection measurements that a nation or business applies, which may explain the limited presence of concrete proceedings in the literature, such as in a discussion of Canada's CIP (Quigley, 2013). Studies within the energy context have more often investigated the reliability of power transmission and how to address cascading failures in power systems (Alvehag and Söder, 2011; Münzberg et al., 2014; Vaiman et al., 2013). Research has also examined power system restoration (Barsali et al., 2008; Soman et al., 2015; Tortos and Terzija, 2012) but has applied a purely technical perspective, which ignores any after-effects despite the potential for serious consequences of cascading failures due to interdependencies in urban settings (Hines et al., 2009). Research in the CI field has often applied modelling and simulation approaches to assess the resilience of networks, such as water distribution systems and transportation networks (Gay and Sinha, 2014; Thekdi and Joshi, 2016) or the interdependencies among CI systems (Robert et al., 2008). Little research has explored planning processes and information procurement and processing in the context of CIP and even fewer studies have scrutinised empirical material from already implemented local, regional and national planning efforts for CIP. This study addresses this gap in knowledge by investigating the Swedish *Styrel* process, which focuses on producing a plan for swift emergency response in cases of national power shortages. This plan intends to protect CI from dysfunction and thereby safeguard society from the negative consequences of a power shortage. The aim of this paper is particularly to clarify the information processing that occurs throughout the implemented national decision-making process to highlight deficiencies in CIP planning.

The *Styrel* process was developed between 2004 and 2011 and executed in 2010/2011 and 2014/2015 (SEA, 2014). It involves many actors from both the public and private sectors, including a large number of national agencies as well as all county administrative boards (CABs), municipalities and power grid operators (PGOs). The planning was executed over a period of more than one year and applied a four-year interval. The next process iteration has started in late 2019 and is running over a period of three years. Due to the global SARS-CoV-2 pandemic, the process is now adjourned for two years (SEA, 2020). Table 1 presents an eight-point scale that the actors in *Styrel* apply as the decision-making aid to identify and prioritise CI in their part of the process.

Table 1 Classification scheme of CI [MSB, (2010, p.10)]

Class	*Score*	*Description of electricity consumers that have/represent*
1	7	Significant impact on life and health – short-term (hours)
2	6	Significant impact on society's functionality – short-term (hours)
3	5	Significant impact on life and health – long-term (days)
4	4	Significant impact on society's functionality – long-term (days)
5	3	Significant economic value
6	2	Significant importance for the environment
7	1	Significant importance for social and cultural values
8	0	Others

In short, the policy-making process commences with national authorities, who identify and prioritise national CI assets. They then pass the information on to the interrelated CABs, which in turn portion the information to the respective municipality in which each asset is located. The municipalities subsequently identify and prioritise further local CI. Then, local PGOs add information about the technical feasibility of directing power to prioritised CI. Finally, information on local rankings is returned to the CAB, which merges the information from municipalities and forwards parts of the final list to interrelated PGOs. They conclude the process with a planning to create conditions to perform a manual load shedding in the case of an emergency.

After this brief description of *Styrel* and the following presentation of the theoretical orientation and methodical proceedings, this paper thoroughly traces and models information paths and investigates the identified information-flawing filters that can affect CIP.

2 Background

2.1 CI, information and protection

A country's infrastructure system consists of a combination of material, institutional and personnel infrastructure (Große, 2018b; Buhr, 2009). Thus, infrastructure is a '*socio-technical system-of-systems*' (Gheorghe et al., 2006, Van Der Lei et al., 2010; Katina and Keating, 2015), which includes all elements, humans, relations and rules that drive the system. Infrastructure becomes critical if people directly or indirectly depend on the continuity of these structures for survival and for progress in a period (Cohen, 2010; Fekete et al., 2012). The European Union has defined CI as

> "an asset, system or part thereof…which is essential for the maintenance of vital societal functions, health, safety, security, economic or social well-being of people and the disruption or destruction of which would have a significant impact…as a result of the failure to maintain those functions." (European Union 2008, L 345/77)

Thereby, the energy sector – and the power supply in particular – appears central to this complex system of CI and its protection (Rinaldi et al., 2001). However, the supply of electricity to CI assets or systems is closely intertwined with the information and communication technology sector and 'sensitive CIP related information' (European Union, 2008). Thus, CIP concerns not only the protection of physical objects from natural hazards and man-made destruction but also the preclusion of unauthorised access to (remote) control systems and the prevention of unauthorised disclosure, altering or loss of sensitive information that is interconnected. Thus, a certain level of information security must be maintained in addition to appropriate degrees of information quality and information preservation. While the former ensures evidence-based decisions on protection measurements, the latter facilitates risk analysis and further development of measurements and processes.

2.2 Information filtration

In order to equip a policy-maker to make well-informed, transparent decisions, a decision support system, irrespective of the type of such system, must provide a quality level for the information basis. Specifically, the information must be of adequate accuracy, timeliness and completeness while simultaneously serving human capability with regard to the format and comprehensibility of the presented information basis. Hence, an information system, regardless of whether it represents the interaction and dialogue between people or the digital information processing by computer systems, must not only collect an appropriate amount of information but also filter and aggregate such information into a proper information basis for decision-making (Bizer and Cyganiak, 2009). During the process of information collection, selection and aggregation, the content passes through several filters – both determined and unintentional – to prepare it for a certain purpose; thereby, several flaws can arise. In particular, if the information processing activities are spread as in a national policy-making approach for CIP, then the collected content proceeds through several analog and digitalised information systems, organisational structures and assessments of individuals, which heightens the risk of flaws in information filtration. The design of the information flow during a planning and decision-making process thus further impacts the information that is processed (Weske, 2012). Fractions in transitions between aggregated sub-processes, different actors or computer systems can establish stages at which information filtration becomes irreversible. Therefore, filters that flaw information during an inter-organisational process are essential for this study on *Styrel*. Of special interest is how information filtration and alteration occur in accordance with formal and informal information paths alongside the Swedish process and how they impact the information basis for decision-making. Since this multi-level planning for CIP involves a large number of actors and extends over a long period of time (Große, 2018b), such information-flawing filters affect subsequent actors during the decision-making process in addition to the quality of the emergency-response plan – and, consequently, the daily life, endurance and progress of society.

3 Method

3.1 Documents and interviews

This study has collected material from publicly available documents and policies that regard the Swedish case and interviews with decision-makers who are responsible for executing the policy-making process at municipalities, CABs and PGOs. As Table 2 indicates, a total of 66 respondents participated in semi-structured interviews, which were typically conducted at the interviewee's usual place of work. This proceeding enriched the evidence with observations of local and organisational conditions of the multi-level planning process.

Table 2 Interview participation

Region	*Size*		*Participants acting on behalf of a*			*Total*
	Area km²	*Population*	*CAB*	*Municipality*	*PGO*	
North	48,935	128,673	1	8		9
Middle	6,075	288,097	2	7		9
South	10,968	1,324,565	1	32	3	36
Further national, cross-regional and local PGOs					12	*Sum: 66*

The interviews lasted one hour on average and were recorded and transcribed. The transcripts complemented the interviews and observations, which were combined with evidence from the document study to allow for data triangulation (Gerring, 2007). The document study included publicly available material from national regulations, a handbook for the planning process (SEA, 2014), evaluations of the pilot implementation of *Styrel* (CAB, 2009a, 2009b), the first run of the complete planning process in 2010 (CAB, 2012; SEA, 2012) and a report on the PGO's scope for manual load shedding (Veibäck et al., 2013). Internal documentation, evaluations and guidelines from interviewees completed the data collection.

3.2 Process tracing and information assessment

This paper examines the formal and informal information pathways in the Swedish policy-making process. The tracing of information filtration and alteration in the local, regional and national proceedings started with an analysis of documentation on the Swedish case, which revealed important background information that informed the subsequently conducted interviews. The study of the proposed reference process also discovered the underlying character of the established information system. Officials at municipalities, CABs and PGOs process the majority of information manually. Apart from standard computer hardware and office software as well as communication by e-mail, digital tools that support the information processing are four spreadsheets, which the entrusted decision-makers should edit on a computer isolated from the internet. The subsequent analysis traces the information processing during the reference process that the handbook proposes and the proceedings during the decision-making process. Interviews and observations at the workplace deepened the information that was gained from the documents. This proceeding verified the evidence and facilitated a differentiated understanding of the Swedish process for CIP.

Previous research has suggested that both the user and the context in which information is generated and utilised are significant for assessing processed information (Strong et al., 1997; Wang and Strong, 1996; Arazy et al., 2017; Bizer and Cyganiak, 2009). In the Swedish case, the actors in the multi-level decision-making process are both creators and users of information, whereas a subsequent planning level employs information from a previous level as input information in the policy-making process (Große, 2017, 2018a). In order to emphasise deficiencies in the information basis for decision-making upon CIP, this study identifies the user, the process environment and the decision-making task and assesses the information processing during the policy-making process (Knight and Burn 2005).

The following section explains and analyses the information collection and creation alongside the *Styrel* process in detail. It also highlights the particular actors and the tasks in which they use the processed information. Subsequently, Section 5 concretises four stages in the policy-making process wherein the information-flawing filters manifest in accordance with the analysis of the traced process.

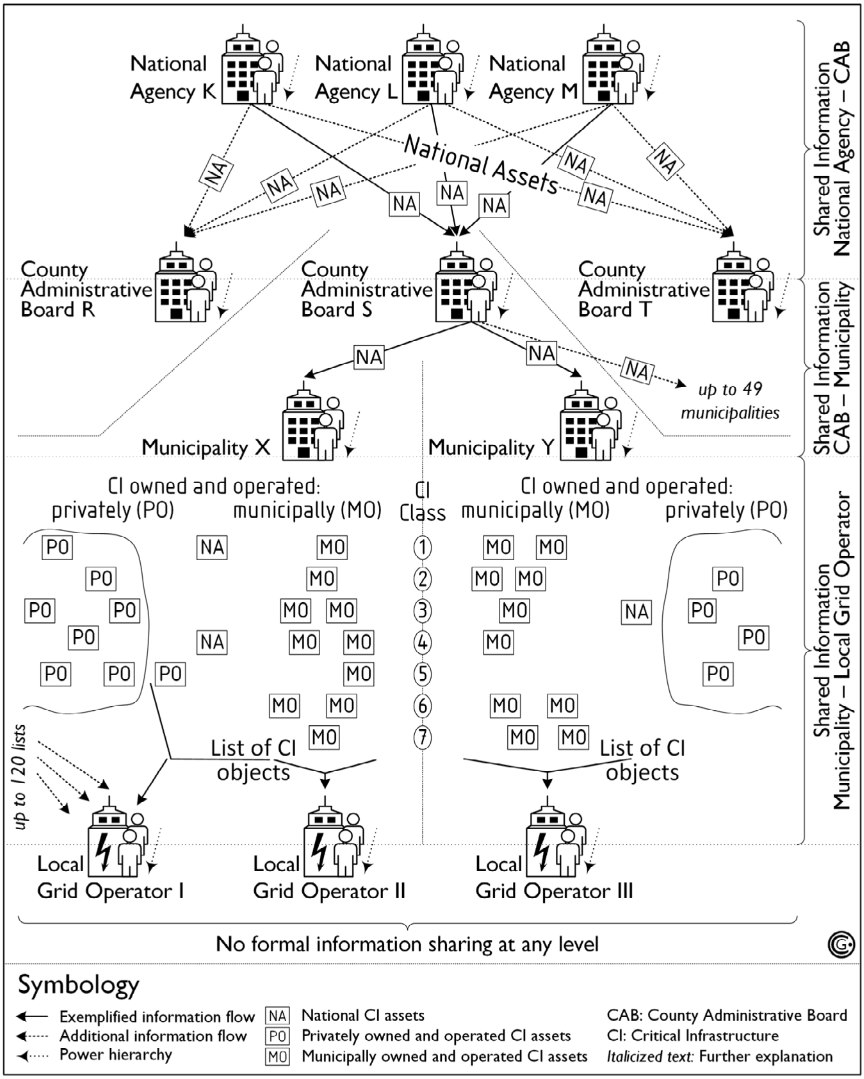
4 Information paths and flaws in Swedish CIP

4.1 Assessment – identification and prioritisation of CI objects

The first filtration phase of the recent iteration of the Swedish planning process (see Figure 1) has a top-down character, during which national agencies and municipalities identify and prioritise power consumers that provide a critical functionality to society. The *Styrel* handbook encourages both actors to involve private organisations in the identification phase because private organisations operate a substantial part of CI. The handbook suggests informing potential private actors and encouraging them to provide relevant information on CI assets that they operate. This proceeding implies a time-consuming process, which may explain the delay due to national agencies during the recent planning process, according to the reports of several interviewees. Despite this intended public-private collaboration, national operating agencies do not necessarily have adequate knowledge of local circumstances or the operators of their assets. In such cases, a national agency can commission the municipalities to identify such CI. However, the interviews reveal that municipalities have almost exclusively focused on municipally operated CI for several reasons, such as the absence of interest from private companies and the lack of time and dedicated resources. Municipalities involve various sources in the identification process, including local registries and maps, individuals with special knowledge of local circumstances and, in rare cases, the local PGO.

The proposed proceedings suggest that the identification phase leads to a national agency creating a new spreadsheet on a Swedish Energy Agency (SEA)-provided template. Apart from identifying information on each CI asset, this document classifies all assets on that list. Table 1 presents the eight-point scale for the prioritisation of these CI objects. A responsible decision-maker who is acting on behalf of a national agency should record the corresponding score for each national asset [NA] on the list and divide the complete document into portions of CI that match each CAB's area of jurisdiction. In turn, the CAB first compiles information on NAs that it has received from all national authorities that participate in the process. As Figure 1 depicts, the CAB then divides this compilation into parts, which relate to the subordinated municipalities' geographic areas of responsibility and it forwards each part to the corresponding municipality in the county. The municipalities proceed with the CI identification and prioritisation similarly to the national agencies and use the information from them as an additional source of insight. Consequently, a decision-maker from each municipality creates a spreadsheet that consists of physical CI assets (national [NA], municipally operated [MO] and privately operated [PO] assets) that are located in the area and their prioritisation class and score. In the final step of this phase, the municipality portions the document into parts, each of which advances to the corresponding local PGO, which directs the power supply to the CI objects on its part of the list. From the municipality perspective, the number of local PGOs varies. The spectrum of collaboration spans from highly close cooperation with one operator – for example, because the municipality owns the grid operating company – to formal letter contact with large providers who are located elsewhere. Interviewees experienced the latter type of contact as less comfortable, with one interviewee explaining, 'the provider is too large – or, rather, it was hard to cooperate with them'. Interviewees at municipalities reported that the closer contact to locally based operators helped them mitigate information sparsity in the criticality assessment of CI by discussing the local interpretation of the priority scale (see Table 1).

Figure 1 Top-down information flow during the identification and prioritisation of CI



Since *Styrel* applies decentralised processing, the reference process regulates neither information security management nor quality management. Because of this lack of system governance, both the protection of sensitive information and the ability to evaluate the results rely on each actor's commitment and appropriate effort. The interviews reflect varying perceptions of the significance of these issues, which may explain why a number of national agencies, such as those concerned with health, post, telecommunication and defense, refrain from participation. Such withholding of information filters and thereby influences, the completeness of information.

Interviewees from municipalities reported another source of misunderstanding in regard to CI objects of regional or national importance. Specifically, they questioned the extent to which municipalities should consider the importance of a CI object beyond its local borders, such as an airport. Such asset could have a higher priority at the regional or national level than at the local level. A similar problem occurs when a company that is located in one municipality in southern Sweden is of immense significance for other municipalities, for example in a county in northern Sweden, or vice versa. Since no formal information sharing is intended to apply between actors, the consequences of CI object classification at the local level cannot be evaluated. In order to fill this gap and advance in the planning process, municipalities generate ad-hoc information when necessary.

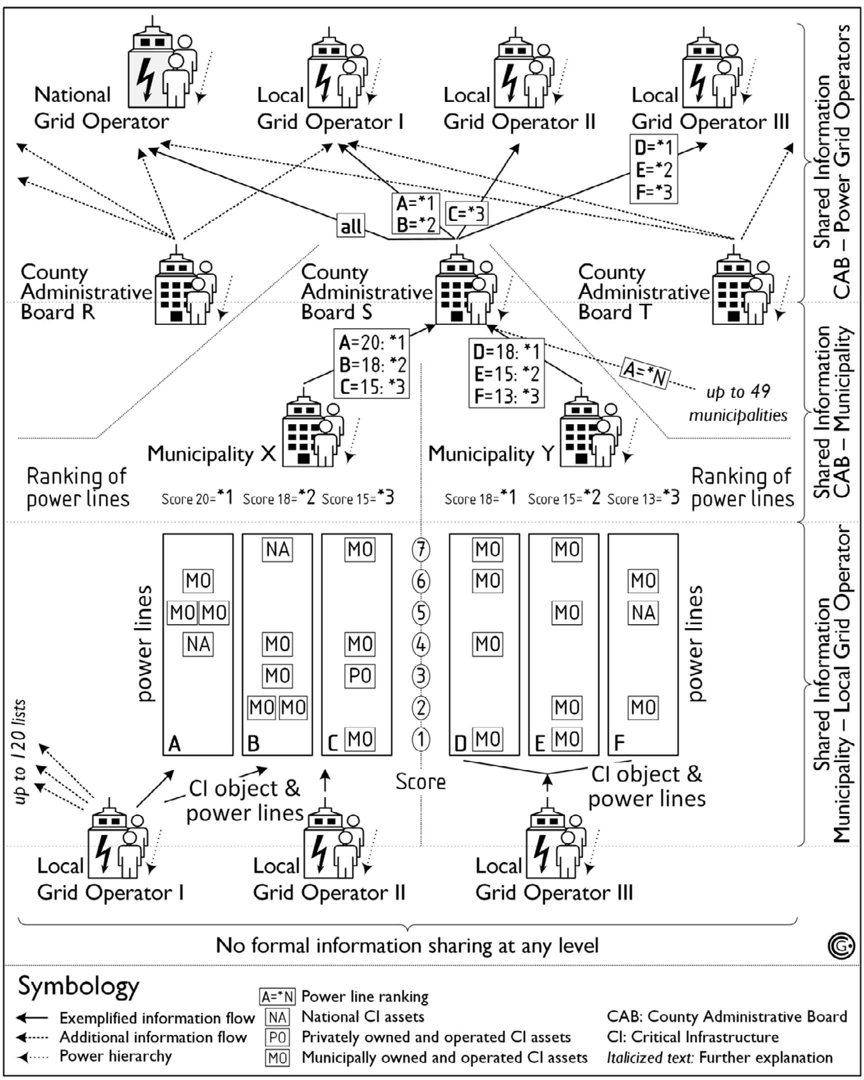
Such separate focus on a portion of CI promotes an overvaluation of the CI's criticality within its own area of responsibility. The interviews indicate that such overvaluation has occurred at both national agencies and municipalities, which has prompted recurring discussions on the matter. The fact that the official handbook opposes a lowering of the designated priority class by a subsequent actor in the process further inflamed the conflict. In view of this, the eight-point scale might be of limited utility for an objective assessment. Because of such information scarcity, which led to difficulties with the classification of CI objects, some CABs have developed their own lists of object types that correspond to each priority class. During the interviews, it became apparent that municipalities tend to classify all assets of the same type as equally critical in accordance with such list, independent of the impact of each object on the surrounding society and without further selection. Such insufficient selection can culminate in a power shortage situation in which power consumption cannot be sufficiently reduced without affecting prioritised consumers. This outcome would weaken the usefulness of the policy that the process produces for the intended situation of application, namely a national power shortage.

4.2 Aggregation – generation and ranking of power lines supplying CI

Although the *Styrel* handbook states that the purpose of the planning process is to reduce the negative consequences of a power shortage for society, the same document indicates that the objective of the process is rather to produce a plan by which PGOs can reduce power consumption during power shortages with minimal impact. Therefore, locally operating PGOs add further information to the spreadsheet from the municipalities, which contains the identified and prioritised CI objects. In particular, each PGO assigns these CI assets to controllable power lines, which the blocks A to F in the lower part of Figure 2 illustrate. In real settings, such lines contain many objects that are classified as CI or non-prioritised. Apart from handling power consumption of non-prioritised consumers during a shortage situation, the amount of CI objects on each power line necessitates an analysis method to support the decision upon the criticality of each power line. In the case of *Styrel*, each CI object receives a score in accordance with its priority class (see Table 1). To generate a local ranking list of power lines, the municipalities use a second spreadsheet that imports a portion of information from the first one. This transfer manifests the second filter; it particularly omits almost all information about any single CI asset. The second spreadsheet applies an additive aggregation to the score of the CI objects that are on each power line. This approach implies that, depending on the number and priority of objects on each line, power lines with CI objects in priority class 1 can have a lower position in a power line ranking. The example in Figure 2 illustrates this issue. Power line A receives a score of 20 and the first position in the ranking list of municipality X. The lines B and C receive the second and the third position respectively.

Both contains a CI asset of priority class 1; line B a national one and line C one asset of local importance. This information though stays in the first spreadsheet, which signalises an intended information loss during the transfer. To mitigate the flaws of the mentioned aggregation approach, the *Styrel* handbook suggests a meticulous reassessment of the automatically generated power line ranking. However, evidence from the interviews reflects that hardly any of the interviewed municipalities reviewed this ranking, mostly because of time limitations or an insufficient understanding of the significance of this step for society when a power shortage necessitates the usage of the produced policy. On the one hand, the expressed motives hope that such situation never occurs; on the other hand, they surrender in view of the sheer amount of data and difficulty of balancing a decision. Moreover, the process ignores power consumers who are not considered 'critical' but are coincidentally located on a prioritised power line.

Figure 2 Bottom-up information flow during the generation and ranking of power lines



Nonetheless, the municipalities transfer the power line ranking information to the second spreadsheet and thereby merge information from all corresponding PGOs in the area. This transfer starts the bottom-up filtration phase of the Swedish CI policy process (see Figure 2). It affects the granularity of information, which, according to the handbook and the interviews, are motivated by information security concerns as well as recurring discussions of variations in municipalities' interpretations of the priority list. In addition, this incorporated information withholding renders it impossible for other actors in the process to validate whether national assets [NA] has been re-classified or not and which CI (municipally operated [MO] and privately operated [PO]) assets are considered in the local assessment. The municipalities then send the second document with the suggested local power line ranking to the associated CAB.

Such ranking disguises concrete object information behind a set of numbers of CI objects in each priority class as assigned to a certain power line identifier. This filtration causes an information loss and CAB interviewees accordingly expressed challenges in generating a regional ranking of power lines. First, each CAB accumulates the information from all municipalities in the region of responsibility into a third spreadsheet for assessing the power line ranking and any comments from municipalities. Second, each CAB identifies power lines that are prioritised by more than one municipality. To eliminate redundant power lines, a CAB manually corrects the values of each line by combining the scores of such a line with the number of objects in each priority class on it. Third, the *Styrel* handbook suggests a further reassessment of the cumulated ranking list by each CAB. Since a power line's score depends on the number of objects that relate to its priority classes, the score of the most important power line of one municipality can significantly differ from the score of that of another municipality and thereby be positioned under a less important power line in the regional ranking. This outcome is questionable for two reasons. First, the *Styrel* handbook advises such regional ranking for all power lines regardless of whether they belong to a PGO. This advice unnecessarily complicates the ranking task because these results do not affect each other in the PGO's current plan. Second, the score does not balance CI's importance between municipalities and neither regional nor national interest. For example, 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. To mitigate this problem, some CABs have created individual strategies.

In one case, the decision-makers at the CAB and the corresponding municipalities made a group decision to rank the approximately 20 to 30 most significant power lines for the region, which also offered feedback for local representation in the regional ranking. The remaining lines fit into the regional ranking list in portions of 10% of each municipality's ranking list until their exhaustion. This group created an ad-hoc normalisation approach due to the scarce provisions for this step in the *Styrel* reference process. In accordance to the CAB interviewee, the group motivated this proceeding with, 'everyone involved though, well, in what other way we are supposed to do it? It is only a freaking long list, so we tried to distribute it as evenly as we could'.

An additional variant of normalisation emerged at another CAB, which first portioned each of the ranking lists from the municipalities into ten parts. The CAB then sorted power lines from the first portion of each list according to:

a municipality preferences

b power line scores

c the number of priority-class-1 objects on a line.

They subsequently apply the same approach to process each of the remaining nine portions. In this case, the CAB solely makes the final decision: ”this was done in order for that the aggregation of the municipalities’ results should be as fair as possible, regardless of their spatial size, their number of inhabitants, or the number of power lines they had ranked”.

During the final step of the bottom-up phase of the *Styrel* process, the current proceeding has implemented a third information-flawing filter. Each CAB creates a final, fourth spreadsheet with the final list and subsequently sends it to the national PGO and dedicates parts of the list to each associated PGO. This final spreadsheet contains information on the name of the county, the power line identifiers, the power grid region and a ranking number for each line. Thus, any information on CI objects is completely lost in this information sharing between CABs and PGOs.

Respondents from PGOs further reported that certain information alters the regional ranking list. They noticed that certain power line identifiers in the CAB documents were not identical to those PGOs provided to the municipalities in the previous step or were even missing. Such lack of information can result in the failure to maintain an important line during a power shortage. Because of the information processing, it is hardly possible for the PGO to track these changes. Respondents argued that this information altering and loss of shared information could be the result of copy-and-paste behaviour, usage of outdated or incorrect data or even unintentional and unnoticed information altering when editing the spreadsheet by municipalities, CABs or both.

Another issue for PGOs accompanies information loss and is due to the design of the information transition process from the local to the regional level. Since the demand for stable power has grown, PGOs have expanded the grid and developed transfer capacities. Such activities have impacted the structure of the grid. One respondent reported that the operator tracked the changes in the grid during certain months of the recent *Styrel* planning and noticed that changes in the power grid structure altered the interconnection of power lines with CI objects. The estimated loss concerns 3% of the companies’ power lines per year, which possibly prevents the prioritisation of important CI in the case of power shortages due to information scarcity.

Similar to the CABs’ difficulty in creating a regional ranking list in view of information scarcity, PGOs that operate many local grids in numerous regions have a comparable challenge of compiling the lists they receive from the CABs in such a way that they match power grid areas. The *Styrel* reference process does not stipulate any approach for this collocation and leaves this decision to the PGOs, which thus establishes the forth information filter.

In Sweden, there are four power grid areas, 21 counties and 291 municipalities. For instance, one of the PGOs that this study interviewed was tasked with information processing for 120 municipalities and 15 CABs. During the information accumulation, this provider first removed duplicate power lines by dedicating such lines to the region that consumes the most effect and assigning the regional ranking, respectively. Then, each power line on a regional ranking list was normalised by its ranking number to the number of lines in that region. The new ranking number was further normalised between competing regions to the highest number of power lines in one of the regions. The compiled ranking lists the power lines in ascending order according to the new ranking numbers. Because of information scarcity, this PGO reported a lack of alternatives and resources to both assess the criticality of the power supply to these lines and update the power supply to CI objects.

5 Implications of information filtration and alteration for CIP

5.1 Deficiencies in the Swedish approach for CIP

Analyses of the process – both the reference process described in the official guidelines and the recent execution of the national process in 2014/2015 – have revealed a set of information-flawing filters, such as information withhold in sharing, information loss when sharing, information scarcity in criticality assessments and ad-hoc information creation due to scarcity. Both the top-down and the bottom-up phases of the *Styrel* planning process have built-in information-flawing filters as a result of the design of the information flows and processing. The previous section has discovered the four stages in the process wherein the information-flawing filters manifest. These four stages can be concretised as follows.

1 identification and prioritisation of CI assets/objects

- incompleteness of the asset inventory
- undifferentiated classification of electricity consumer as critical or non-critical
- disregard of interdependencies among CI
- lack of assessment of dynamic changes of criticality
- lack of negotiation for integrating local, regional and national perspectives.

2 aggregation (I) of assets/ objects into power lines at the local level:

- insufficient automatisation to support the decision upon a local ranking
- automated removal of object information
- ignorance of non-prioritised consumers on power lines
- lack of reassessment due to the amount of processed content.

3 aggregation (II) of all local power lines to a regional ranking at the regional level:

- manual merging of up to 49 local rankings
- lack of common rules to prioritise among local rankings
- lack of means to assess the representation of national and regional CI
- automated removal of any object information

4 aggregation (III) of regional rankings of local power lines for planning of manual load shedding at the power grid level

- manual merging of local and regional rankings

- lack of alignment between PGOs
- lack of means to correct compromised information integrity
- contribution of the produced CIP policy to the mitigation of negative consequences of a power shortage for society is hardly evaluable.

Evidence from this study indicates that this information filtration and altering affects the outcome of the planning and, in turn, the consequences for the dependent society when such plan must be operationalised during a power shortage. In addition, the *Styrel* reference process suggests an occasional annual revision, which seems impossible in light of the presented information creation, loss and altering during the proceeding. None of the interviewees signaled that they had made use of this option. Finally, the information processing during the process obscures appropriate consideration of infrastructure that is critical from a national or international point of view. Thus, because of the information filtration and alteration in the Swedish policy process, unexpected, potentially severe consequences are likely to emerge suddenly in the case of a power shortage, which then urge ad-hoc proceedings during national crisis management.

5.2 Indications for the area of CI policy and future research

The insights from this study of the Swedish approach highlight several difficulties for both research and practice that relate to a deficient information basis in the area. As the results demonstrate, such deficiencies affect not only the decision-making during policy processes but they render a subsequent evaluation insubstantial, which in turn obstructs appropriate developments of CI policy. Therefore, the maturity of national policy networks and processes for CIP cannot be considered sufficient for the purpose of protecting society from the significant impact that a failure of CI can have (e.g., European Union, 2008; Rinaldi et al., 2001; Robert et al., 2008). Although the evidence from this study emphasises that much effort has been made to prevent unauthorised disclosure of information, the altering and loss of sensitive information are not properly addressed. In particular, the intended information suppression that manifests during the policy process significantly reduces the value and relevance of the forwarded information for the subsequent actors in the process. The appropriate degree of information quality has therefore been subject for recurring discussions among the actors in the Swedish policy network; however, the CI policy process lacks suitable criteria that the participating actors can apply to assess information quality during the planning.

In general, the results suggest the establishment of a consistent overall system framework in terms of scope, level of granularity and participation and particular parameters, such as selection criteria and success factors. Enhanced consistency can enable concerned actors to evaluate and compare local proceedings and their consequences for society's safety. In the CIP context, the inherent conflicts between information sharing and information security necessitate particular effort to foster adequate information assessment and management in such inter-organisational settings. Developing and employing an adapted information assessment framework can thus provide a tool to facilitate internal self-assessment by each actor as well as an external audit by an independent body. Moreover, further developments must consider stronger integration of sector-centred approaches into the larger CIP context to facilitate more extensive usage of planning results in other interrelated public-private collaborations. In particular, there is a need to prioritise the formation and maintenance of relevant information channels between the actors who participate in a planning process for CIP, such as *Styrel* and those who this process affects (Große, 2020).

This study contributes to the field of CI by unfolding the information-flawing filters in a decentralised, Swedish approach of policy-making for CIP. However, the collection of research data has been limited due to the information security concerns that the participating organisations and individuals have expressed. Such limitations illustrate that the scholars in the area need to elevate trust between research and practice in order to advance the field of CI policy and CIP practice (Große et al., 2019). Based on the findings of the present study, future research could consider to compare the Swedish policy process with other approaches in the CIP area and the wider field of national risk and crisis management, for example in the European and US context. In addition, further research activities should address the rapid development of CI, which is intertwined with the growing demands of, for example, automated food production and autonomous and electrified transportation and how such dynamics can be properly addressed by cross-sectoral CI policy processes. Finally, the sensitivity of information in the realm of CI advocates reinforced efforts to develop a suitable information management, including considerations with regard to common criteria, a proper data and information quality as well as a tiered information security approach.

6 Conclusions

This study contributes to the understanding of complex decision-making processes that involve a multi-level system of public and private actors in large-scale and long-term policy processes, particularly in the context of CI. The paper addresses the lack of empirical studies of already implemented local, regional and national planning efforts for CIP. More specifically, the research clarifies the information procurement and processing that occurs throughout the national decision-making process called *Styrel*. This multi-level approach to CIP governance is highly dependent on proper collaboration and information sharing between a large numbers of societal actors. The present study has illuminated crucial deficiencies in inter-organisational emergency preparedness and CIP that stem from the complexity of information management in such policy-making processes. Analyses of a Swedish process have revealed a set of information-flawing filters, such as information withhold in sharing, information loss when sharing, information scarcity in criticality assessments and ad-hoc information creation due to scarcity. Both the top-down and the bottom-up phases of the *Styrel* planning process have built-in information-flawing filters as a result of the design of the information flows and processing. The investigation reveals four stages wherein the information-flawing filters manifest and prompt effects, such as the unintended ones similar to playing telephone through the process and the intended information suppression at each of the four stages. Evidence from this study indicates that this information filtration and altering affects the outcome of the planning and, in turn, the consequences for the dependent society when such plan must be operationalised during a power shortage. In addition, the results of this study emphasise that inter-organisational information management between the actors is particularly relevant for CIP, wherein information security and information sharing are important yet conflicting aspects.

Further development of Swedish CIP practice could clarify the activities and responsibilities within the complex system of CI and its protection and governance as well as improve resource allocation at the local, regional and national levels. Further areas of improvement include the alignment of responsibilities and information security measures and the assessment of the suitable granularity of the processed information, the adequacy of access rights and the appropriate information paths. Such improvements can consequently strengthen the integration into risk and crisis management for further usage of the collected information about CI and the ultimately produced protection plan. Moreover, this study indicates future prospects for research in the CIP area. One course of research could link to the case study; research on similar cases in other sectors of CIP or other countries can broaden understandings of the scope and the context of this societal concern. Another research direction could concentrate on the development of methods and tools, especially to enhance trust and collaboration between research and practice even across research disciplines and CI sectors.

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