Applying Systems Thinking onto Emergency Response Planning
Using Soft Systems Methodology to Structure a National Act in Sweden

Christine Groβe
Department of Information and Communication Systems, Mid Sweden University, Holmgatan, Sundsvall, Sweden

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Abstract: This paper outlines a soft systems method approach to model a national preparedness planning procedure for the case of an electrical power shortage. Through the model, we provide a new perspective on enhancing and understanding the joint decision-making environment for the actors involved in the planning procedure, as well as its underlying power structure. By a process of abstraction from the current implementation, a core root definition is presented which provides a generic systems view that can be a useful concept for the study of similar contexts. An action model dedicated to determining meaningful and valid activities is derived, providing insights for the improvement of collaborative emergency response planning in general. The paper, thus, aims to contribute to the communication and cooperation between actors and stakeholders in the development of appropriate decision processes and decision support in the context of emergency preparedness.

1 INTRODUCTION

The constant availability of electricity is, nowadays, a precondition for many parts of infrastructure. It is demanded in almost every part of our day-to-day lives and businesses. Since lacking power affects essential functions of a society's common life, it constitutes a key sector of critical infrastructure (CI). Cascading consequences can harm other sectors of CI and, thereby, affect the industry and population which depends upon them (Rinaldi et al., 2001). These consequences can occur locally, affect a larger community, and also involve global interests. Thus, proper planning of the power supply is necessary. Variations in electricity generation related to consumption can also lead to risk situations in the supply network, which have to be balanced to maintain the reliability of power delivery (Maliszewski and Perrings, 2012).

Due to the dimensions and climate conditions of Sweden, providing electrical power to every inhabited place is challenging for both humans and materials. Maintaining a distributed power grid needs permanent effort. Since infallible protection against all kinds of power shortage seems to be an impossible task, proper continuity management and emergency response planning can help to handle adverse events and alleviate the consequences of them. Sweden's power generation and supply landscape is fragmented due to the privatisation of the electricity market in 1996 (Bergman, 1997). This fragmentation hampers decision paths and complicates communication between the individuals and groups responsible for electrical power in Sweden. In order to manage continuous power delivery, many of the necessary adjustment operations are automated. Nevertheless, in the case of power shortage, a response plan can support reliable decision making. Besides an analysis of the societal consequences, the planning needs to consider responsibilities, a previously defined chain of order, plausible and documented priorities, and a structured approach, enabling an operations team to reach the goals of reconditioning and maintenance while causing as little subsequent problems as possible (Johansson and Hassel, 2014).

Contingency planning – preparing this solid basis for an operational emergency response – depends on information sharing and cooperation between the stakeholders involved (Pramanik at al., 2015), and their perception of a crisis (Nilsson, 2010; Penrose, 2000; van Laere, 2013). The combination of various stakeholders being involved, with their own points of interest and responsibilities, and the sensitivity of the power grid, is expected to cause tensions. The added fact that these tensions can impact interdependent CI impels the following study.

The study investigates the planning process and circumstances with a particular focus on the

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stakeholders involved, their interrelations, and the belonging context. The leading research question is:

Which elements of a conceptual system model should be considered during emergency response planning, regarding power supply within the complex context of critical infrastructure?

Since the problem situation appears to be not particularly well-structured, with unclear objectives, a soft system analysis and modelling approach has been chosen to meet the conditions appropriately (Avison and Taylor, 1997). The remainder of the paper reads as follows: after briefly describing the background of systems thinking and the response planning approach, the research process is outlined. After the system analysis, the conceptual system model is presented and discussed, related to the associated context. Final remarks conclude the paper and outline the prospects for further research.

2 BACKGROUND

2.1 Systems Thinking

The term "system" has been discussed for more than half a century. This discussion provoked a number of concepts and opinions. This paper falls short of defining the term in general; rather, the concepts underlying the study and research-leading points of view are marked. Systems can be considered to be '*complexes of elements standing in interaction*' (Bertalanffy, 1968, p. 33). Interactions in this quote suggests that relations between elements are not linear, and by that trivial – rather, they are complex and do not necessarily have correlations by causality or determinism. Searching for a generally valid theory to describe phenomena inside, between and around systems gave rise to the General System Theory, which emphasis its interdisciplinary character by accepting both mathematical and sociological analysis techniques (Bertalanffy, 1968, p. 2). The open system, standing in an exchange relationship to its environment, crosses system borders in useful interaction (Bertalanffy, 1968, p. 141). This illustrates the challenges to set system boundaries, and not only in the context of response planning. The fact that individuals can be seen as elements in one or several systems can result in conflicts in goals and behaviour. The intention to provide a universal approach to all kind of system led to a hierarchical classification of complexity according to corresponding individuals (Boulding, 1956). In this hierarchical order, the social system appeared at the top in terms of complexity. Evidently, influences on power structures and group behaviour, as well as individual target tracking, within and between systems, are all related to this order. It complicates the predictability of interactions and the ensuing decisions within a social system.

Furthermore, modern societies and organisations are characterised by the use of many technical systems. The functionalities of the technical part of a complex system can influence the social environment. In turn, the knowledge and behaviour of an intended user influences the outcome of a technical system. A socio-technical system, as a holistic system, is able to achieve a better outcome than the parts standing alone (Emery and Trist, 1960). Particularly important is the ability of the human, as part of the system, to create improvement and add value to the system (Mumford, 2006). Moreover, their adaptability of behaviour in emergencies is an important aspect for system resilience (Boin and McConnell, 2007).

Besides the technical infrastructure, the power-delivery system relies on the willingness of decision-makers in case of power outages (Maliszewski and Perrings, 2012). This unbalanced power relation requires intervention by the government to preserve societal interests. If conflicts between groups of interests arise, a balancing of risks is required to avoid the damage that could be caused by conflict escalation (Wimelius and Engberg, 2015). In addition, an observer's perspective in his or her role as a system analyst can be biased, which raises further potential for conflicts. An analyst has to respect constitutive characteristics while introducing an observed system to analysis; namely they are: different points of view, events and decisions, interconnectivity and a topic as limitation (Kieser, 2001; Rüegg-Stürm, 2001).

Hence, two dimensions of governance have resulted from the deliberations above, providing a basis for response planning: the *horizontal* – structures for processes, with resources and responsibilities, and the *vertical* – structures for organisation, e.g., power structures within a system. Thus, consequent coordination of the information flow through a system, both horizontal and vertical, provides adequate conditions for communication and cooperation between interrelated elements of a system. A case of particular importance is the response planning system in Sweden regarding the power supply to key consumers in the context of CI.

2.2 Response Planning in the Context of the Power Supply in Sweden

The national planning procedure regarding the power supply during an event of power shortage, named *STYREL*, was prepared since 2004 and tested by its first iteration in 2010-2011. Purpose of the procedure is to gather data on the infrastructure that depends on electricity. A particular focus lies on the identification of consumers whose activities are essential for national society, with regards to health, safety and interdependent businesses. Consumers are ranked in advance to ensure immediate decision-making during an emergency either caused or accompanied by lacking electricity. Due to the amount of involved departments and companies, the structured approach was developed for an ascertainment of priority lists.

The second iteration (2014-2015) was launched by the following national authorities: (1) the Swedish Civil Contingencies Agency, (2) Energy Department, (3) Swedish Energy Markets Inspectorate, and (4) Swedish national grid provider, Svenska Kraftnät. National agencies identified electricity consumers at a national level, and categorised them depending on their importance to national societal functions. This categorising was conveyed to the county administrative board (CAB) where the respective consumers were located. CABs initiated the operation within their regional area. They provided information to municipalities and called for action. Municipalities identified and ranked key power consumers locally. Local grid operators assisted with details regarding technical feasibility. Lists of categorised consumers were returned to the CAB. Each CAB assessed the data collected from a regional perspective. If power lines cross county borders, adjacent counties had to categorise those lines together. The consumer ranking was finally forwarded to local, regional and national grid providers as a basis for their response planning. (Energy Department 2014)

3 RESEARCH PROCESS

3.1 Soft Systems Methodology

The methodological research concept used in this paper is grounded on the Soft Systems Methodology (SSM) approach developed by Checkland (1972), aligned with the design-oriented research process of *analysis, design, evaluation*, and *diffusion* used in information system research (Österle et al., 2011).

The entire process of SSM in its classical form constitutes seven stages (S) (Checkland, 1989): *S1*: Enter the situation that is considered problematic, *S2*: Express the problem situation, *S3*: Formulate root definitions of the relevant systems, *S4*: Build conceptual models of the systems named in the root definitions, *S5*: Compare the models with real world situations, *S6*: Define possible changes which are both possible and feasible, *S7*: Take action to improve the problem situation.

SSM is arranged in this way to explore different views stakeholders concerned with a situation can have, and to achieve shared understanding about relevant and necessary actions. The object of this approach is to provide structure to a complex problem situation. This structure is used to determine activities that are able to improve the initial situation. SSM is used with similar intentions, exploring complex situations and meeting various stakeholder needs, often in the early stages of systems development (Cundill et al., 2012; Hakami et al., 2013; Mendoza and Prabhu, 2006; Sørensen et al., 2010).

3.2 Data Analysis

S1 is performed within and across documentations and notices about the current planning process. The literature selected is limited to the outlined case and given context in order to gain a holistic understanding of the observed system and its interacting elements. Different interests in the situation and existing correlations are investigated alongside. Discovering significant roles and power structures is part of the argumentative-deductive analysis, as well as exploring the system environment and boundaries. Various criteria are applied to analyse the case. Thereby, individual interpretations by the system observer were kept to the margins for a qualitative text analysis. The epistemological goal of the analysis is to explore what the current situation characterises.

3.3 Conceptual Model Design

Results from the data analysis constitute the systems-thinking foundation for the content of the conceptual system model. Furthermore, the sub-models are based on each other to obtain, step-by-step, a higher level of abstraction. The purpose is to detach the thinking from the current implementation of the planning case in Sweden, and to yield a generic analysis concept for complex response planning situations. For reasons of generality, no explicit modelling language is applied; instead, the model design is based on the figures of SSM used in the literature (e.g. Checkland and Scholes, 1999; Proches and Bodhanya, 2015).

In the course of *S2*, a ‘Rich Picture’ is created that represents individuals and groups, their conceivable concerns, technical and environmental elements, and interrelations between the components. Researchers’ interaction with the case enriches the model. This can require several iterations to deal with structures (Grochla, 1974; Mingers and Taylor, 1992).

During *S3*, a root definition is formulated that represents a generic system model for planning a power-shortage response. Besides the system definition, the research considers the elements of CATWOE (Smyth and Checkland, 1976), see Table1.

Table 1: Elements of CATWOE, after Checkland and Scholes, 1999, p. 35.

Element	*Description*
Customers	The victim or beneficiaries of T
Actors	Involved persons in / Performer of T
Transformation Process	Conversion of input to output
Weltanschauung	Big picture that makes the T meaningful in the context
Owner	Ruler who could stop T
Environmental constraints	Elements outside which it takes as given

In *S4*, an action model is derived from the root definition, establishing a bridge between concept and practice. The leading question for building this sub-model is: What are the purposeful activities necessary to carry out the specified transformation process, T? Individual interests and goal conflicts are reduced by focusing on the generic root definition.

3.4 Evaluation and Further Steps

During *S5*, the sub-models are compared with a real world situation. Several methods are suggested to perform this step; using formal questioning is the most common (Checkland & Scholes, 1999, p. 43), and is also used in this study. Several stakeholders were confronted with the models during interviews. Eight security coordinators, representing all of the municipalities of one rural, sparsely-inhabited county in northern Sweden, participated in qualitative interviews. In addition, two experts from a local grid provider were questioned. Seven of the people interviewed were involved twice, one of them once, and two had no practical experience in the procedure. The interviews varied in length but generally took about one hour, and are recorded and transcribed.

S6 encourages a debate about the changes that are possible and feasible. Changes to the investigated situation suggested during the performed interviews are presented. Furthermore, conceivable changes regarding the models, in order to adapt them to a broader context, were also debated with the experts.

S7 motivates actors to take action to improve the initial situation. Contributions towards achieving a conceivable improvement of the situation are indicated in the discussion and conclusion section. Attending the implementing process of the possible changes, however, is not part of the current research. SSM promotes a continuous circle using conscious critical reflection and learning (Checkland and Poulter, 2006, p. 61). This circle is supported by the diffusion of the current research results.

4 SOFT SYSTEM MODEL

4.1 Results of the Analysis

Throughout the analysis, documentations regarding the case were examined using the following questions: (A) Which components exist and are relevant to the situation? (B) What are the concerns of the identified components? (C) How do the components relate to each other? (D) Within what context are the components embedded?

Several system components were discovered. On the one side, municipalities, country councils and national authorities are charged with response planning. On the other side, national, regional and local grid providers are responsible for executing the contingency plan in case of a power shortage. In addition, local grid providers are also involved in the planning process, cooperating with the respective municipalities. On top of this, four national responsible authorities, as mentioned in 2.2, initiate the planning procedure. Since the roles of the components within the situation are different, various concerns arise; s like: how shall the practical work be performed? Is the plan feasible, according to technical conditions of the grid? Who will be affected by the decisions made? How can the resulting response plan be used? Moreover, relations between system components can cause the grounds for further concerns. They can be based on power structures as well as on discomfort regarding collaboration or workload. As a result of the separation between planning and execution, without adequate feedback, the commitment of actors may fade away during day-by-day business. This can also affect awareness about the contextual frame. Aside from that, the complexity of the context provides an obstacle to holistic planning, although the holistic view is a necessary requirement for investigating all interdependencies. Since a power shortage can have cascading effects on other infrastructures, national security, the economy, and society can all be affected. Not least, power production and distribution also leads to thoughts about economic and environmental issues for many of involved parties. The system components and their interactions in the context derived from the analysis

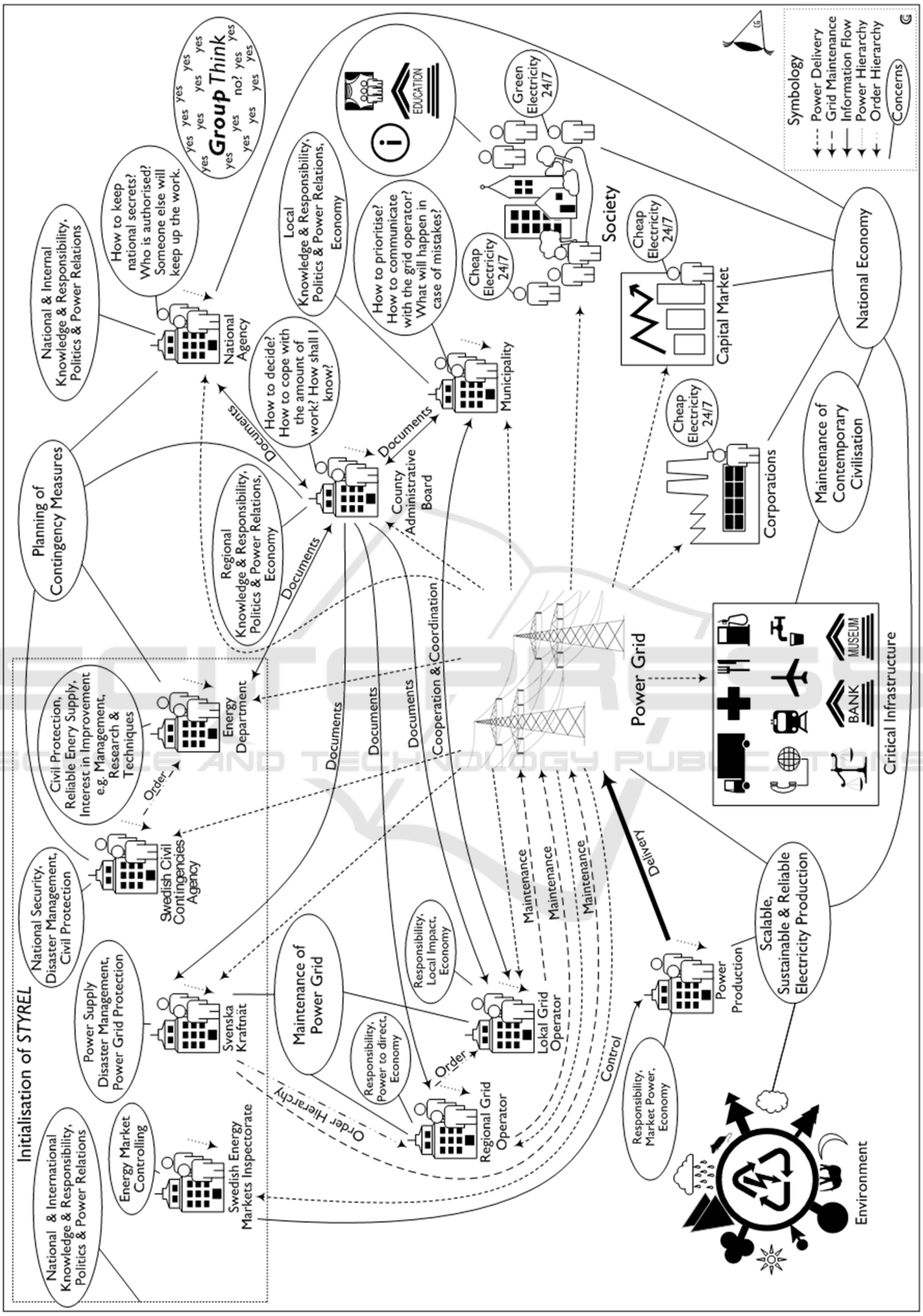

Figure 1: Rich Picture of the Problem Situation.

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interactions in the context derived from the analysis above provide the basis for the representations in the next section, which elaborates on the conceptual model performing *S2 - S4*.

4.2 Conceptual System Model (1-3)

4.2.1 Rich Picture of the Problem Situation

The first sub-model of the conceptual system model is the *Rich Picture,* representing the current national constellation, as shown in Figure 1. It contains the elements, their relevant concerns, and relations in the specific situational context discovered during the analysis. Following SSM, the picture includes several different concerns and a certain level of subjectivity. Concerns are exemplary and represent a selection across the conceivable spectrum of matters. Doubts that an individual party has can also be a concern of another party or both parties, exactly as it can be an inappropriate concern.

Besides the national authorities, which initiate the planning process, other decision makers and responsibilities are shown. Their particular concerns and relations between each other are displayed. Moreover, the illustration expresses connections and (inter-) dependencies between society, environment, other CI, and the national economy, as well as the industrial and financial sectors. The fact that all of the actors within the situation also depend on power delivery is represented by dashed arrows between the power grid and the actors. Specific notable aspects appear as labels, figurative expressions, and thoughts. The latter uses straight lines with balloon messages assigned to actors. The dotted arrows indicate a hierarchical order structure within an organisation.

4.2.2 Root Definition of the System

Derived from the case analysis and the Rich Picture, the core root definition of the generic system is prepared and provided in Figure 2 below. This definition represents a generic system to support decision-making on the controlled disconnection and delivery of electricity in the case of a power shortfall.

The owner of the system (O) is the government, because it has the authority to cancel the entire transformation process (T), which constitutes the core concept of the system. Furthermore, the government has a long-term interest at a higher level in the societal and ethical aspects of the process. The grid operators are identified as the intended customers (C) of the system. Their decision-making shall be supported by adequate means produced during the transformation process of the system. Various actors (A) operate inside the conceptual system. These are professionals with different kinds of experience and decision-making power. Between them, various structures of communication and cooperation arise. The Weltanschauung (W) states that decision-making is

Core Root Definition

A government-owned system, staffed by local, regional and national qualified professionals, which, considering legal regulations and technical limitations, supports planning and preparedness. It provides relevant information for decision-making on power supply in the case of power shortage. The system collects and prioritises power consumers that meet the criterion 'important to society' in order to preserve and maintain critical infrastructure during a crisis situation that makes an impact on local, regional or national society.

C	*grid operators of all kind (local, regional, national)*
A	*experts and professionals within municipalities, local grid operators, county councils and national authorities*
T	*need for supported qualified decision-making to enhance resilience – need met by structured information about power consumers*
W	*planning of decision-making is achievable and enhances emergency management*
O	*government*
E	*legal regulations and technical limitations of the grid structure*

Figure 2: Core Root Definition of a Generic System to Support Decisions on Power Allocation.

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something that can be planned, which enhances emergency management. From the system-owner's perspective, it may also represent another long-term interest to support the resilience of the critical system. Legal regulations as well as technical limitations in the control abilities of power grid components constitute the environmental constraints (E) of the presented generic system.

4.2.3 Action Model

An action model, as Figure 3 demonstrates, is designed following the statements in the core root definition, which help to abstract the thinking from the current implementation. The model presents relevant actions during response planning to obtain support for decisions on power allocation in case of a power shortage. To identify power consumers in need is one of these actions. Classification criteria are needed as well as an understanding about how to use them, observing potential subjectivity. Associated emergencies and their different requirements for decision-making and measurement constitute the crisis scenarios. Moreover, technical limitations to power grid control have to be investigated. Power consumers are classified using criteria. Grid-control abilities affect how consumers can be served.

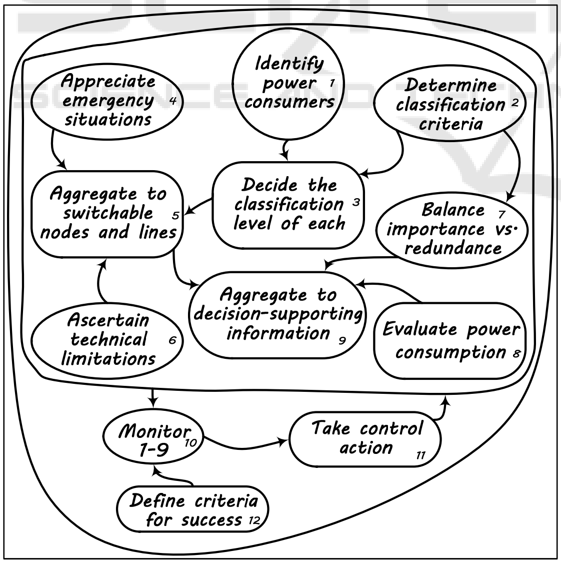

Figure 3: Conceptual Action Model.

Balancing between importance and a reasonable level of redundancy within a region influences information aggregation. Information about power consumption completes the decision.

The monitoring and documentation of the process steps, and results of decisions made, are both necessary to ensure the quality of the process and to provide a basis for improvement. Defined performance criteria assist in the appreciation of the success of the approach and enable the people responsible to take control actions in case of variation. Due to the fact that various actors within the public and private sectors involved in the system, individual goals can differ and the system owner may request an adequate control ability. This control subsystem controls the activities performed during a transformation process by means of a feedback loop.

4.3 Debate and Further Action

The conceptual system model, containing the sub-models, was presented during semi-structured face-to-face interviews. The participants was encouraged to compare the models with the real-world situation. Open-ended questions were asked in order to gain stakeholder perspectives and individual opinions.

Although the Rich Picture was considered to be complex and full of detail by all at the first glance, after a short time and closer inspection, the content and interactions became clear and the participants themselves became interested in further discussion. Many wanted to talk about details that they were particularly interested in. Often, these details were related to their own experiences and concerns. However, aspects concerning the work of others were also noticed with interest. There was a strong consensus that CI and possible cascade effects caused by a power shortfall are central points of their planning work. All of the participants expressed the opinion that the Rich Picture could be used to heighten the general public's awareness regarding the complexity of the situation. In addition, many said they would like to see this picture implemented as a form of interactive training, which would enable the individuals responsible to explore the situation, as well as the planning and response procedure, as a process by themselves, step-by-step.

The root definition and the action model were approached with slight difficulty by some, and were perceived as being less accessible than the Rich Picture. After a short investigation, this opinion changed fast. Participants could see benefits in the generality and experienced the activities as valuable and reasonable. Almost all of the people interviewed could imagine using the action model in other emergency preparedness planning settings too. Some participants mentioned a desire to have a more straightforward process model providing more distinct sequences for the activities. All participants considered a control cycle to be important for their planning work, which is notably absent in the existing emergency response planning procedure.

The participants felt that more time for detailed consideration, and also further discussion with other actors involved in the procedure, would be desirable. Such collaboration can help people to exchange insights, gain a shared understanding about "expected performance", and, not least, to overcome flaws within the procedure. Further changes and actions was suggested as follows: (A) The usage of the resulting response plan needs clarifying, (B) The expected engagement during the planning activities needs to be communicated, (C) A feedback-loop has to be initiated to improve the procedure and to help actors to stay motivated, (D) Adapted how-to guides for planning activities can be developed in order to lower entry barriers, particularly for new personnel.

5 DISCUSSION AND CONCLUDING REMARKS

One recurring concern in studies within emergency management in Sweden is the need for adequate information paths: both *inside* a system, between actors during planning activities, and *outwardly,* to affected people and groups during emergencies (Enander et al., 2015; Hansén, 2009; Olofsson, 2011; Palm, 2009). Formal and informal practices to reach dedicated stakeholder groups have been presented.

This paper provides an informal basis for establishing communication and encouraging collaboration. First, a Rich Picture was designed, based on the literature analysis. It visualises the structures and (inter-) dependencies between the stakeholders involved, and their communication paths related to the planning process. All known actors are included and their concerns are exemplified. Since the space is limited, just a few issues are specified. However, they do not exclude additional relevant concerns, nor are the formulated thoughts limited to one special group of stakeholders. During the interview, one participant remarked that the secrecy ascribed to the exchanged information was not noted in the picture. Aside from the fact that this can be done easily, the intention during modelling was to keep the complexity manageable for the beholder. Such supplementary information can be valuable and readily interpretable in interactive representations or adapted views concerned with specific aspects, such as information security.

Deduced from the case and problem situation, the core root definition of the generic system was then outlined. The system definition abstracts from the concrete real-world setting, and focuses in on the purpose and circumstances of a generic system, as well as on responsible actors within their different roles. While establishing the core root definition, abstractions are made to obtain a generally valid system definition, with respect to the aim intended by the initial case.

The action model completes the conceptual soft systems analysis model. Meaningful and generally valid activities are developed by an investigation of the core root definition with respect to the research question. The model provides insights for improving collaborative response planning to power shortages. The people interviewed appreciated the value of the generic action model during overarching national response planning. They also perceived its usefulness in other contexts, such as water and fuel emergencies, and even in a more holistic approach for emergency response planning generally. The action model can be adapted to other national or sector-based contexts, e.g., by using modified keywords. It can also be used as a tool to consider conceivable dependencies and local, regional, and national resilience. It makes no claims over the due sequence of activities within an associated transformation process respective process model. Therefore, developing a (reference) process model can be an activity supporting change, according to *S7*. In consequence, the level of flexibility will be reduced for the advantage of lower entry obstacles and a relieved work flow. In the specification of such a model, responsibilities should be formulated and the adequate implementation of a feedback loop considered. In addition, security concerns can be specified, as well as determining authorisation levels regarding access to information.

Furthermore, another control cycle can be modelled in addition to the action model. This second control cycle controls the kind of monitoring, the success criteria, and the control actions needed in order to enable supervision of the controlling activities. Key indicators that facilitate the controlling of the level of success are called the '3 Es' in SSM. Those are *efficacy*, *efficiency* and *effectiveness,* and can be added to the activities and the first control cycle of the action model presented in Section 4.2.3. Thus, it can be assessed whether the measurements work, whether the right activities are performed to meet long-term interests, and whether resource allocation is sparing (Checkland, 1989). The indicator *efficiency* needs careful consideration in the context of power allocation, since efficiency and resilience are slightly contrary concepts. The government should not only put trust in communities' ability to adapt and be resilient (Bulley, 2013); it also has to encourage partnership and communication in order to reach the favoured collaboration before, during and after a crisis (Powley, 2009; Ödlund, 2010). Such indicators were not detected through the case analysis and interviews. Within the paper, performance indicators are not substantiated due to the generality of the conceptual soft system analysis model.

Since power allocation for power consumers, besides technical constraints, comes with ethical and political concerns, the SSM approach was considered to be informative by the respondents in this paper. As described in Section 4.2, the approach provides a means for structuring the complex situation of collaborative national response planning. The case reported on herein, *STYREL*, shows that emergency response planning is characterised by multiple stakeholders providing different views and perspectives in a distributed environment. Section 4.3 suggests that SSM enabled an open mind-set among the people interviewed, facilitating discussion and suggestions for improvements. As such, increased comprehension of this type can provide a good basis for further improvement of organisational learning and knowledge management. In consequence, these improvements can provide a solid support for achieving reliable decision processes and support for decisions. Thus, applying SSM in the current stage of the emergency preparedness and response planning process resulted in an improved understanding of the complexity of the process and the relationships between the involved parties.

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