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Abstract

A conceptual framework for systematically studying and analysing risk governance is introduced. The framework, which is influenced by design science, is particularly valuable for relating the way risks are handled at the micro-level to aspects at the macro-level. Three central concepts are included in the framework: purpose, function, and form. A *function* is used to denote *what* a specific system does, or needs to do, to achieve the *purpose* of a risk governance process. The *purpose* of a risk governance process answers the question *why* it exists, or why it should be introduced, while the *form* denotes *how* the functions are, or should be, carried out in practice. The framework is especially useful as a basis for identifying problems related to a fragmentation of the risk governance process in contexts involving multiple stakeholders. Moreover, it allows descriptive, evaluative, as well as normative approaches. In this way, the framework manages to connect two central types of problems. On the one hand it addresses the problem of understanding and explaining a risk governance process (descriptive approach) and, on the other hand, the problem of constructing, or improving it (normative approach). The usefulness of the design perspective is exemplified in two cases, and the findings from both of these cases indicate a fragmentation of the risk governance process.

Keywords: risk governance, design science, design perspective, risk management, fragmentation

INTRODUCTION

Risks facing our modern society have become increasingly complex (OECD, 2003). As a result of the growing number of interdependencies between different societal functions, a failure affecting one system can easily propagate to other systems (Amin, 2000; Little, 2002, 2004). In this way, crises are not confined to sectorial, jurisdictional or national borders, but have become increasingly trans-boundary in nature (Ansell, Boin, & Keller, 2010). This complexity characterising the technologies underlying our modern society makes risks difficult to predict and control (Carroll & Fahlbruch, 2011). Moreover, at the same time as many elements in society, including for example critical infrastructures, have become increasingly interconnected, the design, management, operation and maintenance of these systems are nowadays often divided between a larger set of stakeholders (Almklov & Antonsen, 2010; de Bruijne, 2006). What once was an intra-organisational task has changed into an inter-organisational undertaking, in which large networks of stakeholders who often have competing interests, are involved (de Bruijne & van Eeten, 2007).

As a result of the shift from intra-organisational to inter-organisational operation and maintenance of various critical functions in society, many risk-related decisions need to be taken in multi-actor settings, in which no single stakeholder has superior authority (see e.g. van Asselt & Renn, 2011). The traditional approach to dealing with risks, based on the elements of risk assessment, management and communication, has been described as too narrow to adequately handle risks in such contexts (Renn, Klinke, & van Asselt, 2011). In addition to these classical elements for handling risk, the literature in the emerging field of risk governance emphasises the need for also taking into account the ways in which risk-related decision-making is performed in settings where many stakeholders are involved, and where these different stakeholders hold diverse meanings of the concept of risk (IRGC, 2006). Risk governance research therefore also stresses the need to pay attention to the legal, economic, social and institutional

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contexts in which risks are managed (Hermans, Fox, & van Asselt, 2012), and the concept of risk governance has accordingly been defined as "the various ways in which many actors, individuals, and institutions, public and private, deal with risks surrounded by uncertainty, complexity and/or ambiguity" (van Asselt & Renn, 2011: p. 432).

With the aim of providing guidance on strategies to cope with risks at the global level, the International Risk Governance Council (IRGC) has presented a framework for risk governance (IRGC, 2006). This framework comprises a sequential process including four major phases: pre-assessment; risk appraisal; tolerability and acceptability judgment, and; risk management (IRGC, 2006)[5]. However, this framework has been criticised for failing to take into account the micro-level processes in which risks in practice actually are managed, and hence, the framework has been claimed to represent an "idealistic" and "decontextualizing" approach to risk governance (Boholm, Corvellec, & Karlsson, 2012; see also for example Löfstedt & van Asselt, 2008; Renn & Jäger, 2008; Rosa, 2008 for other critical comments on the IRGC framework). In existing approaches to risk governance, limited attention has thus been paid to the link between macro-level processes (i.e. the processes taking place on the level of society, including the vertical as well as horizontal interplay between different public and non-public actors) and micro-level activities (i.e. the decisions and actions taken by specific individuals, and the specific documents produced).

The objective of this paper is to contribute to an increased understanding of the ways that micro-level processes give rise to macro-level challenges to managing risks in settings characterised by a multiplicity of actors and perspectives. More specifically, we argue that this type of insights can be gained by adopting a design perspective of risk governance. By using this perspective, we show how two distinctly different risk governance processes in Sweden can be analysed with respect to how specific tasks are performed (micro-level) and how that affects macro-level functions in the systems of interest. Moreover, the analyses also illustrate that the suggested approach can be used to detect problems related to a fragmentation of the risk governance process (see e.g. Klinke & Renn, 2012; Renn et al., 2011). By fragmentation we mean situations where the output from one part in the risk governance process cannot be used, or is difficult to use, as input to another part. Detecting such problems would have been difficult by focusing solely on the micro or the macro level in isolation.

We start the paper by outlining what we mean by a design perspective and by describing the conceptual framework we use. Next, we introduce two systems in which we analyse risk governance in Sweden; one related to railway transportation and one related to the national crisis management system. Then, we present the results from analyses of the two systems and explain how the results can be interpreted using the design perspective. Finally, we offer some conclusions regarding the governance of risk in the two systems of interest and regarding the usefulness of the approach employed.

APPROACHING RISK GOVERNANCE FROM A DESIGN PERSPECTIVE

Risk governance can be studied from many perspectives and involving many levels. However, since it is at the micro-level that the actual decisions and negotiations over risks take place (Boholm et al., 2012; Vaughan, 1996), we emphasise the need to include this level in the analysis. It is argued that it is from an understanding of these activities that the practical challenges to risk governance can be identified, and hence, improvements of the risk governance process can be suggested. Thus, what is needed is a way to draw conclusions regarding risk governance in a specific system (macro level) based on observations at the micro-level (decisions, negotiations, documents, etc.), i.e. a way of linking several levels of analysis. The approach used here to establish such link is influenced by design science (Simon, 1969). Several authors have argued that design science is different compared to "traditional" sciences such as natural science and social science; see for example Romme (2003), Peffers et al (2007), and Horva (2004). The key point is that the mission of design science is "...to develop knowledge for the design and realization

[5] In addition to these four phases, communication and stakeholder involvement are described as closely related concepts to all of the phases (see e.g. Klinke & Renn, 2012).

of artefacts, i.e. to solve construction problems, or to be used in the improvement of the performance of existing entities, i.e. to solve improvement problems" (van Aken, 2004: p. 224). On the other hand, the mission of what van Aken calls explanatory sciences, which includes "...the natural sciences and major sections of the social sciences", is "...to describe, explain and possibly predict observable phenomena within its field" (van Aken, 2004: p. 224). We believe that a design science perspective on risk governance can help us understand the relevant phenomena better and to facilitate the transformation of that knowledge into concrete advice on how to improve a specific situation. Thus, design science (with its focus on achievement of purposes) can be a valuable contribution to the aspiration of risk governance research to cover both descriptive problems as well as normative ones (see for example van Asselt & Renn, 2011).

The most direct way that design science influences our approach to understanding risk governance is through the use of Rasmussen's abstraction hierarchy (Rasmussen, 1983, 1985)[6]. The idea of the hierarchy is that any complex socio-technical system can be described using different levels of abstraction: the highest level corresponds to the purpose of the system in question, and the lowest level corresponds to the system's physical form (Vicente, 1999). The levels between the purpose of the system and the physical form are connected to the levels above and below in a means-end relationship, i.e. the lower levels represent means to achieve the end of the higher levels. The number of hierarchical levels that are employed in the description of a system depends on the type of system and the purpose of the study (Naikar, Hopcroft, & Moylan, 2005; Rasmussen, 1985). Here we choose to adopt Brehmer's approach of using three levels of abstraction, i.e. *purpose*, *function*, and *form* (Brehmer, 2007)[7].

Each level in the hierarchy corresponds to answering specific questions regarding the system of interest. The purpose level answers questions like "*Why* does the system exist?", the function level answers questions like "*What* does the system do in order to fulfil the purpose?" and the form level answers questions like "*How* does the system carry out the necessary functions?". In Figure 1 the three levels are illustrated together with the keywords Why, What and How that represent the questions that are associated with the different levels.

Level of abstraction	Answers question
Purpose	Why?
Function	What?
Form	How?

Figure 1: The three levels in the abstraction hierarchy together with the associated questions.

[6] It is important to note that Rasmussen originally developed the abstraction hierarchy from the analysis of dialogues between people working in complex systems. He did not use the abstraction hierarchy as a support for design. Instead that aspect of the hierarchy has been developed by others, for example (Brehmer, 2007).

[7] It is important to note that the hierarchy should not be seen as representing a one-to-one relationship between purpose and form, and thus, it is misleading to talk about *the* purpose of a system. Instead, the same form can serve multiple purposes and one purpose can be fulfilled by many different forms.

As stated above, there might be many different purposes associated with the actions taken by the various stakeholders that are involved in the management of risk. Nevertheless, from a design perspective it seems reasonable to assume that a general purpose of risk governance processes is to allow various stakeholders "to reduce, mitigate, or control the occurrence of harmful outcomes resulting from collectively relevant risk problems in an effective, efficient, and fair manner" (Klinke & Renn, 2012: p. 278). A specific process will probably be associated with an even more specific purpose. For example, a risk governance process may be performed in order to manage a specific class of risks (e.g. natural hazards), a specific risk-related situation (e.g. transport of nuclear waste), or a specific type of risk (e.g. mad cow disease). By *risk governance process* we mean the set of activities and actions taken by various stakeholders to manage risk in a context characterized by uncertainty, complexity and ambiguity.

Moreover, there is typically no single stakeholder who has the overall responsibility for a specific risk governance process. Nevertheless, for analytical reasons, it is necessary to describe a purpose (or several purposes), at least if the analysis is conducted with the aim of detecting "risk governance deficits" (see IRGC, 2009; see also Aven, 2011, for some remarks on the notion of risk governance deficits) and suggesting improvements. However, if we were to engage in the study of risk governance in a system only having the purpose as a point of departure, we would be faced with a very difficult task of providing an answer to the question of how risks are managed in the system of interest. Instead, we suggest that the overall purpose of managing risk in a specific system should be broken down into a set of functions that are needed to achieve the purpose. In this way, the most central term in our conceptual basis is the term *function*. The term risk governance function is used by Klinke and Renn (2012) to denote the various activities comprising their risk governance framework. In this paper, a similar, but more operationalized, meaning is given to the term function.

In our view (following Brehmer, 2007), a function is a theoretical concept, much like a mathematical function. It is a representation of what a system *does* and it is defined based on the *output* it produces. The function itself cannot necessarily be observed in the system of interest, but the output can. The term is used to provide a link between the macro perspective and the micro perspective. From a means-ends point of view, the functions provide answers to the question "what does the system do to achieve its purpose?" (see Figure 1). The functions that are needed/performed in order to manage risk in a context characterized by many stakeholders, complexity, uncertainty, and/or ambiguity are related to our theoretical understanding of the concept of risk governance. As noted above, one such common model of risk governance has been provided by IRGC (2006). Each of the phases, or parts of the phases, in that model can be associated with a specific output, and in accordance with the concepts used here, we can define functions that corresponds to that output. For example, according to IRGC "Risk governance deals with the identification, assessment, management and communication of risks in a broad context" (IRGC, 2008: p. 4). These activities are possible to be described in terms of their output. For example, the function *Risk identification* might be defined as the function that generates output in terms of a description of a set of "risk sources […], events […], their causes and their potential consequences" (ISO, 2009: p. 4). In this way, the emphasis on outputs makes our use of the term *function* more operational compared to the use of the concept adopted by Klinke and Renn (2012).

Although the *functions* of a system represent *what* the system does and the *purpose* describes *why* this is done, we need to investigate its *form* to determine *how* it is accomplished. The form of a system is the most concrete description of it. For example, many risk governance processes are likely to involve the function *Risk identification*. However, *how* this function is performed will most likely differ considerably between different contexts. There will be different stakeholders involved, different methods applied, different ways of describing the results, etc. The form is what we can study in practice, i.e. it is on that level that the output of the functions can be investigated.

Studying risk governance from a design perspective can be performed using different points of departures and different approaches; see Figure 2 (see also Brehmer, 2007). One alternative is to use a descriptive approach, which assumes that there is an existing risk governance process that we want to study. The descriptive approach answers questions about the purpose, function, and form of such a process. This approach can be complemented by what we refer to as an "evaluative" approach. The aim of the evaluative approach is to use a specific purpose as a point of departure and to investigate whether an

existing system (form level) actually fulfils it. This type of analysis can be employed to identify risk governance deficits (see IRGC, 2009), and it can also provide a good starting point for managing the deficits. The descriptive and the evaluative approaches are applied in the examples presented later in the paper. Finally, the potential problems, or deficits, identified by using the evaluative approach may be further addressed by using a normative approach, with the aim of suggesting how risk governance *should* be conducted. For studies of existing risk governance processes, the three approaches can thus be used sequentially. In Figure 2, we show which types of questions might be asked depending on which approach and which level in the abstraction hierarchy that is in focus. To illustrate how real risk governance processes can be studied from a design perspective, we describe two examples below.

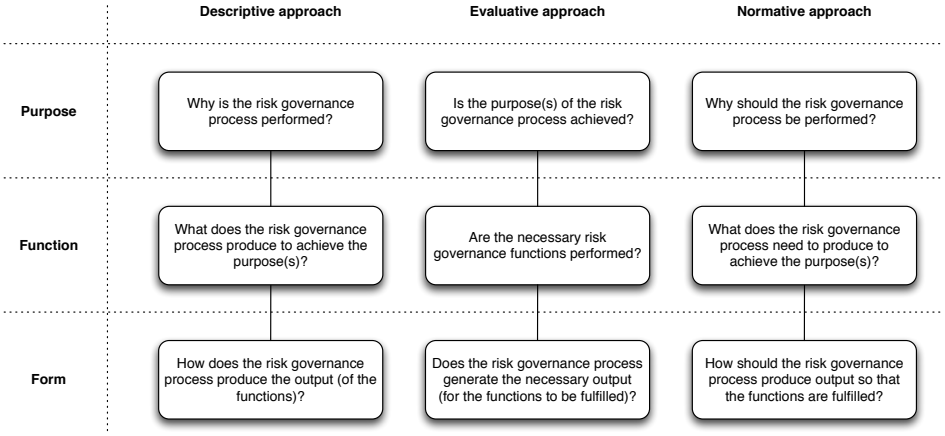

Figure 2: Illustration of risk governance from a design perspective, involving three analytical approaches.

APPLYING A DESIGN PERSPECTIVE

The empirical data underlying the two examples were originally presented in Cedergren (2013a), Abrahamsson and Tehler (2013), Hassel, Abrahamsson, Eriksson, Tehler, and Petersen (2012) and Lin, Nilsson, Sjölin, Abrahamsson, and Tehler (2013). The examples include two very different contexts of managing risks in multi-actor settings. The first example involves the process related to safety improvement and management of risk in the Swedish railway sector and the second example focus on a part of the national Swedish crisis management system.

CASE 1: ACCIDENT INVESTIGATION AND IMPLEMENTATION OF RECOMMENDATIONS

Describing purpose, functions and form

The first example concerns the process of accident investigation and implementation of the recommendations following serious accidents in the railway system[8]. The example includes both a descriptive as well as an evaluative approach. Starting with the descriptive approach, the first step involves the identification of the purpose of the risk governance process in question (see the box at the

[8] The view on risk governance adopted in this paper is not limited to the efforts of identifying, assessing, and managing risks in a forward-looking perspective, but also involves the processes of accident investigations and similar backward-looking approaches in which risks are identified and managed. The first example of using the design perspective relates to this backward-looking viewpoint.

top-left of Figure 2). This purpose can be found in the Railway Safety Directive of the European Union (Directive 2004/49/EC: Article 19 1§), which is the European directive regulating railway safety. In this directive, the purpose of conducting accident investigations is described as achieving "improvement of railway safety and the prevention of accidents".

In order to fulfil the overarching purpose of improving railway safety and preventing accidents, a number of necessary activities are described in the regulatory framework. These activities are here referred to as functions in accordance with the conceptual framework described in the previous section, and they are defined based on the output they generate. These functions include *Accident investigation*, *Formulation of safety recommendations*, and *Implementation of safety recommendations* (see Figure 3).

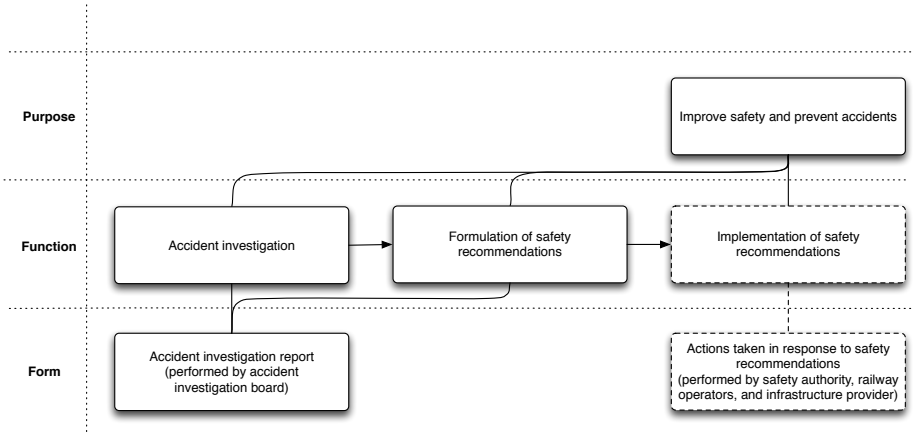

Figure 3: Illustration of the Swedish system for official accident investigation and implementation of recommendations seen from a design perspective.

In the Railway Safety Directive, these functions are further specified in a way that allows us to describe their output. An accident investigation is described as a process involving several activities, including "the gathering and analysis of information, [and] the drawing of conclusions, including the determination of causes". The output from each of these activities can be seen as separate functions, and in this way, the example shows that each function can be broken down into even more detailed sub-functions, all of which describe *what* needs to be done in order to meet the overall purpose. Since these activities are difficult to separate in practice (i.e. it is difficult to operationalize the output from each of these sub-functions), they are here treated under the overall function of *Accident investigation*. The output from this function is the identification of causes to a specific accident or incident.

The second function is referred to as *Formulation of safety recommendations*, and is characterised by a description of measures deemed necessary for achieving the overall purpose of preventing recurrence and improving safety. The third function is referred to as *Implementation of safety recommendations*, and this function can be defined by the actions taken following each recommendation. As further described later in this section, the function of *Implementation of safety recommendations* is only studied indirectly in this paper, and for this reason, it is illustrated by dashed lines in Figure 3. Identification of these functions corresponds to the second level of the descriptive approach illustrated at the left hand-side of Figure 2.

The functions *Accident investigation*, *Formulation of safety recommendations*, and *Implementation of safety recommendations* are common to all countries in the entire European Union to which the European Directive on railway safety (Directive 2004/49/EC) is relevant (and elsewhere in accordance with similar directives). Still, the way these functions are accomplished in practice varies. In other words, there are many ways of producing the outcome of the three functions described above. This shows the difference between *what* is necessary to do in order to achieve a specific purpose, and *how* it is achieved.

In order to study risk governance, it is necessary to find the specific form of the various functions, i.e. to study *how* they are accomplished. A natural point of departure is to identify the various stakeholders that are involved in the risk governance process, and subsequently determine *how* the various functions are fulfilled by studying *what* the different stakeholders do. In Sweden it is the national accident investigation board (the Swedish Accident Investigation Authority) that conducts railway accident investigations and formulates safety recommendations. By studying the accident investigation reports produced by this body, we can draw conclusions regarding *how* the function of *Accident investigation* is conducted. Moreover, the reports also include recommendations for improvement, which means that they also show how the function of *Formulation of safety recommendations* is performed. In the case of the third function, *Implementation of safety recommendations*, the output of interest is the actions following the recommendations that result in a change of the railway system. In the present context it is primarily the railway infrastructure provider (the Swedish Transport Administration) and the railway operators who implement the recommendations. Although we do not investigate the actual implementation, we have access to feedback reports from the safety authority (The Swedish Transport Agency) to the investigation board (the Swedish Accident Investigation Authority) that includes descriptions of those recommendations that have been implemented and those that have not. Thus, by studying these reports, conclusions can be drawn with regards to *how* the function related to *Implementation of safety recommendations* is conducted.

Evaluating form, function, and purpose

A second step of the analysis of the form-level is related to determining whether the form fulfils the functions (i.e. the evaluative approach). At the time of data collection, the safety authority had provided feedback reports with regards to the implementation of a total of 105 recommendations. From an analysis of this material, it was concluded that causes were identified and safety recommendations were formulated in all of the studied accident investigation reports. In this way, the functions of *Accident investigation* and *Formulation of safety recommendations* were producing output. However, all of the recommendations were not implemented. More specifically, the results from a content analysis of the feedback reports from the safety authority to the investigation board revealed that almost one out of five (19 out of 105, which corresponds to 18%) of the recommendations did not result in any implemented actions (see Table 1). In addition, the findings showed that for 28 % of the recommendations, actions were planned but not yet initiated (see Cedergren, 2013a, for further detail). This implies that the number of recommendations that are not followed by any actions may in fact be higher. These results suggest that one or more functions that are necessary for the fulfilment of the purpose in question do not produce the required output. We wanted to investigate this in more detail in order to discover why these recommendations were not implemented (or not completely implemented).

Table 1: Proportion of all recommendations followed by implemented actions (Cedergren, 2013a)

Category	Number of recommendations	Proportion of all recommendations
Actions taken and completed following the recommendation	13	12 %
Actions initiated but not completed following the recommendation	45	43 %
Actions planned but not initiated following the recommendation	28	27 %
No action taken, initiated, or planned following the recommendation	19	18 %
Total	105	100 %

Following the observation of the recommendations that were not implemented, an interview study was

conducted in order to explore the challenges related to implementation of recommendations. These interviews (which are more extensively presented in Cedergren, 2013a) included 14 respondents from 4 types of organisations involved in the process of accident investigation and implementation of these recommendations, including: the safety authority (n=2); the accident investigation board (n=3); the infrastructure provider (n=4); and five different railway operators (n=5). The findings from these interviews revealed two major challenges to implementation. First of all, it was concluded that some recommendations were misdirected (i.e. they were directed at a stakeholder who did not have the mandate to implement the suggested measure) due to limited knowledge of each other's roles and mandates. In this way, the function *Formulation of safety recommendations* sometimes did not match the subsequent function of *Implementation of safety recommendations*. Secondly, it was concluded that the receivers of the recommendations in some cases did not fully understand the link between analysis (i.e. identification of causes) and the suggested recommendations on remedial actions. More specifically, the receivers of the recommendations experienced an analytical gap between these functions, since they found it difficult to see in what way the specific causes justified the suggested recommendations (see Cedergren, 2013a, for further detail). Thus, the form of the output, i.e. the documents, from two of the functions (*Accident investigation* and *Formulation of safety recommendations*) was difficult to use as input to the third function (*Implementation of safety recommendations*).

To recap, the results presented in the previous paragraphs showed that some functions were not fully connected to one another due to limited awareness of each other's roles and mandates, as well as the existence of an analytical gap between different risk governance functions. Because of this, the functions did not fully give rise to the overall purpose of improving safety and preventing recurrence of railway accidents. In this way, each stakeholder fulfilled their role and mandate from an intra-organisational perspective, while these efforts were not always fully optimal from an inter-organisational point of view. By adopting the framework outlined in this paper, it was thus possible to identify challenges related to a fragmentation of the risk governance process, which would have been difficult if this area was studied only from a micro- or macro-level perspective.

CASE 2: THE SWEDISH SYSTEM FOR RISK AND VULNERABILITY ASSESSMENTS

As a part of their crisis management systems many countries have established national systems for risk and vulnerability assessments. They are constructed based on an all-hazards approach and involves a variety of different stakeholders in the effort to manage risks (European Commission, 2010). The focus is often on systemic risks (OECD, 2003) that have the potential to cause significant consequences if the events associated with them should occur. The Swedish system for risk and vulnerability assessment (RVA-system) is composed of stakeholders on the local, regional and national levels. More specifically, on the local level, there are 290 local municipalities conducting risk and vulnerability assessments focusing on their municipality. On the regional level, there are 21 County administrative boards conducting regional assessments and on the national level, there are several authorities conducting risk and vulnerability assessments focusing on their area of responsibility. For example, the Swedish Transport Agency (Transportstyrelsen) conducts risk and vulnerability assessments for the transport sector. Moreover, the Swedish Civil Contingencies Agency (MSB) produces a national risk and vulnerability assessment using input from the other national authorities and the County administrative boards. In addition to these public stakeholders, there are numerous private ones contributing to the process.

Describing purpose, functions and form

Our example here is focused on one of the purposes of the RVA-system, namely that of being able to provide national, regional and local overviews of risks and vulnerabilities. The example is described in detail in Abrahamsson and Tehler (2013), while the main focus here is to illustrate the design perspective. Specifically, we focus on how this perspective can help us to understand how the system in question works and how it can be used to evaluate the extent to which the purpose is achieved. Similarly to Case 1, the purpose can be found in the relevant Swedish legislation as well as in the official reports and preparatory work that preceded the current legislation. Through a content analysis of the relevant

documents it was concluded that one of the purposes of the RVA-system is "To generate a comprehensive overview of risks, vulnerabilities and emergency management capabilities at all levels, local, regional and national" (Abrahamsson & Tehler, 2013: p. 81).

The next step in our analysis of the RVA-system involves investigating which functions are performed so that the purpose stated above is fulfilled (corresponding to the second level of the descriptive approach showed in Figure 2). Thus, we ask w*hat* the system in question does in order to fulfil its purpose. The results from an analysis of the relevant legislation and an investigation of definitions of risk and vulnerability indicate that in order to produce an overview of risks and vulnerabilities, it is necessary to describe scenarios, consequences and associated uncertainties (see Abrahamsson & Tehler, 2013). Therefore, we conclude that the Swedish RVA-system fulfils its purpose (to produce national, regional and local overviews of risks and vulnerabilities) by producing estimates of what might happen (scenarios), what the consequences might be, and associated uncertainties. It is important to note, however, that estimates of scenarios, consequences and uncertainties are necessary, but not sufficient, products of the RVA-system. In addition, it is necessary to provide an *analysis* of risks and vulnerabilities; otherwise it would be difficult to use the results for decision-making (since they would merely be a collection of scenarios, etc.), which is what the *overview* of risks and vulnerabilities is produced for. We use the term *Risk identification* to denote the function that generates estimates of scenarios, consequences and associated uncertainties. This use of the term is in agreement with the ISO-definition (ISO, 2009) with the exception that the ISO-definition does not explicitly mention uncertainty. To turn the output from the *Risk identification* function into an overview of risk requires another function, which we call *Risk analysis*. This is also in agreement with the definition in the ISO-standard, which defines Risk analysis as a "process to comprehend the nature of risk [...] and to determine the level of risk" (ISO, 2009: p. 5). Thus, the *Risk analysis* function uses the estimated scenarios, consequences and uncertainties as one input to produce an output that is an assessment of the level of risk.

Moving down to the lowest level of abstraction in Figure 2 implies asking *how* the functions of *Risk identification* and *Risk analysis* are performed in the Swedish RVA-system. According to Swedish legislation relevant in the present context, the different stakeholders within the system are supposed to send risk and vulnerability assessments (reports) to each other on a regular basis (Abrahamsson & Tehler, 2013). These reports are then supposed to be used as one input to the process of constructing the overviews of risks and vulnerabilities. For example, the County administrative boards are supposed to use the risk and vulnerability assessments of the local municipalities as one basis for their assessment of risk and vulnerabilities in the region. Furthermore, the national level (MSB) is supposed to use the risk and vulnerability assessments of the County administrative boards (regional level) and the other national authorities to produce the national overview of risks and vulnerabilities.

We can now illustrate what we have found in the Swedish system with respect to the purpose of providing overviews of risks and vulnerabilities on various levels of society. In Figure 4 we show that the function of *Risk identification* (and *Risk analysis*) is supposed to operate on different levels (national, regional and local). The output from that function is a set of scenarios, consequences and associated uncertainties. The output is then used as an input to the *Risk analysis* function, which produces something that is more suitable for decision making, e.g. various measures of risk, maps with geographic information related to risk, presentation of the level of risk etc. In the figure below, we have used dashed lines to represent that function since it is not the focus here. Instead, it is the *Risk identification* and its output that is of interest. In Figure 4, we also illustrate that the functions that are supposed to be operating on the various levels in practice are realized through the creation of documents called risk and vulnerability assessments. These assessments contain output from the *Risk identification* function, i.e. descriptions of scenarios, consequences and associated uncertainties, but they also contain output from the *Risk analysis* function such as, for example, estimates of level of risk. Therefore, the separation of the output from the functions is often not easy in practice (form level). However, even though the output from the functions coexist in the same physical document, it is often easy to identify those that are descriptions of scenarios, consequences and uncertainty, and those that are assessments of level of risk and the recommendations. The documents are required by law to be sent upwards in the administrative

hierarchy and thus, they form a connection between the different *Risk identification* functions (national, regional and local).

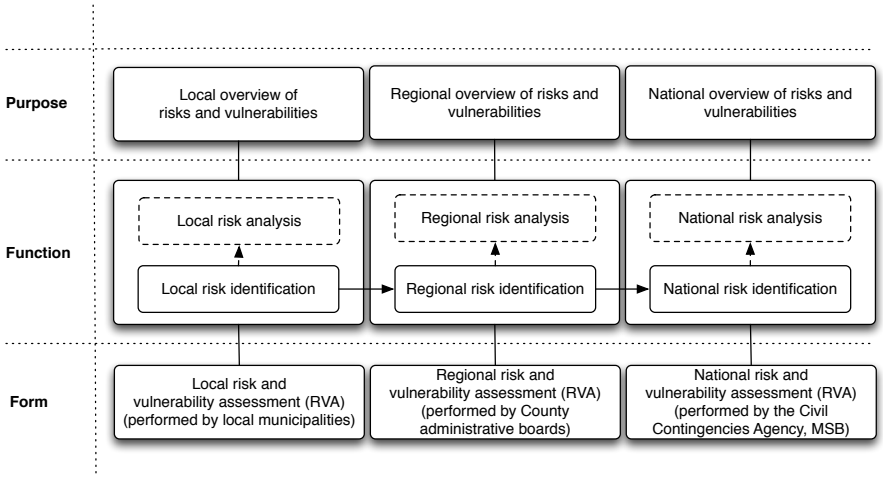

Figure 4: Part of the Swedish RVA-system seen from a design perspective.

Evaluating form, function and purpose

So far we have only studied how the system works (i.e. a descriptive approach). Now we will focus on whether the system achieves its purpose. We then need to determine if the output of the system in question (form level) is sufficient for the associated functions to be fulfilled (i.e. an evaluative approach, see Figure 2). In Abrahamsson and Tehler (2013), such an analysis is presented for the regional *Risk identification* function. In practice, the output of the function is contained in the risk and vulnerability assessments that are produced annually by the 21 County administrative boards in Sweden. All analyses from the years 2008 and 2010 were included in the analysis. An important conclusion from that study is that the results, i.e. information concerning the scenarios, consequences and associated uncertainties, are presented in many different ways by the County administrative boards. For example, some of the assessments present consequence estimates using one dimension, such as the number of fatalities in case of severe events, whereas other assessments do not include that dimension. Furthermore, they also differ in terms of the scale they use to present the consequence estimates. Some do not use scales but instead use descriptions of consequences with no natural scale to express how serious the consequences are perceived to be. Others use qualitative (ordinal) scales, i.e. scales where it is possible to rank the order of seriousness of various scenarios. Yet others use semi-quantitative scales (ordinal scale with the addition of numbers representing the consequences, e.g. 100 fatalities). The same observation can be made with regards to the assessments of how likely the scenarios are. Some of the assessments do not provide assessments of likelihood; others use qualitative scales, etc. Tables 2 and 3 summarise the results from the investigation.

Table 2: The way estimates of consequences are expressed in RVA documents from the 21 County administrative boards in Sweden. The documents are from 2008 and 2010 (Abrahamsson & Tehler, 2013).

	2008	2010
No consideration of consequence	2	2
Verbal description	6	7
Qualitative scale (5 classes)	11	11
Semi-quantitative scale (5 classes)	2	1
Quantitative estimates	-	-

Table 3: The way estimates of likelihood (of specific scenarios) are expressed in RVA documents from the 21 County administrative boards in Sweden. The documents are from 2008 and 2010 (Abrahamsson & Tehler, 2013).

	2008	2010
No consideration of likelihood	6	4
Verbal description	2	5
Qualitative scale (5 classes)	9	8
Semi-quantitative scale (5 classes)	4	4
Frequency or probability	-	-

Similar studies have been performed focusing on the RVAs produced at the local level. Lin et al. (2013) and Månsson et al (2013) describe investigations of a total of 71 RVA documents sent by the municipalities in three counties in Sweden (Stockholm, Skåne and Örebro) to their respective County administrative boards in 2012. The conclusions with respect to the form in which scenarios, consequences and associated uncertainties are presented are similar to the findings presented in Tables 2 and 3. Thus, there is a significant variation in terms of how important aspects of risk are communicated. Moreover, an interview study performed in 2012 also confirms that the form in which scenarios, consequences and associated uncertainties are presented in the RVA documents is highly variable in Sweden (Hassel et al., 2012). 25 actors (organisations) on the local (15), regional (5) and national level (5) were included in the study, which also suggests that not only are the output in terms of the RVA documents different, but the actors' ways of working also differ.

In conclusion, the investigations of local RVAs (71 documents), regional RVAs (21 documents from 2008 and 21 documents from 2010), and the interviews with the 25 actors on the local, regional and national level in Sweden suggest that although the function of *Risk identification* does produce output on all levels, the form of the output is not suitable to be used as input for the *Risk analysis* function on neither the regional nor the national level. The reason is that due to the variety in ways the assessments of scenarios, consequences and associated uncertainties are presented, it is very difficult to produce an overall assessment of risk. For example, if one local municipality has estimated the consequences of a flood to be "very serious", it is not easy to relate that statement to a statement from another local municipality stating that the consequences of a flood is estimated to be the loss of 200 million Swedish crowns. Therefore, it becomes difficult for the County administrative board to use the local municipalities' RVAs as a basis for their own assessment (at the regional level). The problem is that the assessments in the two municipalities are expressed using different scales, which are hard to relate to each other. The same problem occurs at the national level when the County administrative boards'

assessments are to be used as input to the national assessment together with assessments from each of the national authorities.

From a design perspective, one can argue that the *Risk identification* function on the local level is producing output that is not suitable as input to the corresponding function on the regional level. The same conclusion can be drawn regarding the relationship between the regional and the national levels. This does not mean that the documents that are sent between the various stakeholders are not useful, but rather that they are of limited value for the specific purpose of producing overviews of risks and vulnerabilities on different administrative levels. Thus, similarly to Case 1, we can conclude that there is a fragmentation of the risk governance process. In this case, the fragmentation occurs between the *Risk identification* and *Risk analysis* functions on different administrative levels.

DISCUSSION

The rationale behind the framework presented in the present paper stems from the fact that many risks facing our society are managed in settings involving multiple stakeholders at different levels, where no single stakeholder has superior authority. In this type of institutionally fragmented settings, the output from a specific risk governance function (carried out by a specific stakeholder, or a set of stakeholders) provides the input to another risk governance function (carried out by another stakeholder, or a set of stakeholders). Although this kind of division of labour can have positive effects, such as increased efficiency, it may also imply that more attention is directed towards the partition of a task than on the coordination of the sub-tasks in order to create a whole (Heath & Staudenmayer, 2000; Kramer, 2005). When communication and coordination between stakeholders responsible for different parts are restricted, this kind of setting may give rise to a "multi-organisational sub-optimisation" (Hill & Hupe, 2002), i.e. a process wherein each individual stakeholder is pursuing its individual goals and objectives, but with outcomes that are not ideal from a holistic point of view (see also Ostrom, 1999; Woods & Branlat, 2011). For this reason, it is of significant importance that the kinds of approaches presented in this paper are developed, which specifically address the activities going on at the interfaces between various stakeholders involved in the governance of risk (and the output they produce).

An important issue to highlight is why it is useful to study risk governance from a design perspective. We believe that there are at least three aspects that demonstrate the benefits of adopting the design perspective. First of all, it provides a conceptual as well as a practical link between descriptive and normative studies. By providing such a link the design perspective facilitates the transformation of insights gained concerning risk governance deficits (evaluative) into suggestions on how to deal with them (normative). It thereby contributes to the aspiration of risk governance studies to cover both descriptive and normative perspectives (cf. van Asselt & Renn, 2011). Secondly, it facilitates comparison of different risk governance cases. To compare the ways that risks are managed in different contexts is difficult. One important reason is that attention is often directed to the concrete form without guidance on what to look for. Therefore, it might seem as if two cases, for example risk governance in the Swedish and the Nicaraguan crisis management systems, appears to be completely different (see Rivera & Tehler, 2014). They employ different tools, different procedures and they organise themselves in different ways, etc. However, when studying the situation from a design perspective and focusing on the functions of risk governance they might be more similar than they first appear. Thus, the output from the risk governance functions might be similar (and possible to compare) despite the different means (form level) of producing it. Finally, the design perspective enables continuous contributions to a common knowledge base. Similarly to when comparing different cases, the functions provide a way of systematizing our knowledge related to risk governance. Through multiple studies in different contexts it becomes possible to develop hypotheses that relate the form of the processes to the output of the functions. For example, if studying the function of *Risk identification* in several cases one might discover that the presence of certain factors (form level) appears to lead to a better output (function). Such hypotheses can then be tested in yet other circumstances to see if they are general or only applicable to a certain contexts. Moreover, such descriptive hypotheses can be developed into design propositions that provide guidance concerning interventions that should improve risk governance (see Denyer et al., 2008).

Design propositions that are field tested (see van Aken, 2004), i.e. they have proven to work in practice, and grounded on scientific knowledge, i.e. we understand the mechanisms leading to the outcome, are very valuable when dealing with normative problems. However, the examples used to illustrate the design perspective here do not include a normative approach. Therefore, examples that demonstrate how the design perspective can be used to suggest solutions to identified problems (or "risk governance deficits") needs to be described in the future. Moreover, when this normative approach is applied, the need for participation and communication between the various stakeholders, which has been raised by several authors (see e.g. IRGC, 2006; Klinke & Renn, 2002), needs to be highlighted. While communication and deliberation in general terms sometimes are treated as a panacea for improving the governance of risk (see Löfstedt & van Asselt, 2008), the use of the framework presented in this paper gives more specific clues regarding what needs to be communicated. For example, in the first case in the present paper, it was clear that ambiguities related to each other's roles and mandates need to be clarified in order to improve the risk governance process. In the second case, it was clear that communication regarding common ways of expressing different types of estimates in RVAs would be valuable in facilitating risk identification on higher administrative levels.

The cases presented in this paper might give the impression that various types of documents are the only ways that communication over risks takes place in the systems of interest. This is, however, not the case, since it is likely that, in addition to the exchange of reports, there are also many other forms of communication between persons working in the various organisations on the various administrative levels where risks and vulnerabilities are discussed. Nevertheless, since the documents are the only thing that the stakeholders are required to share, and that the information contained in them are quite difficult to convey verbally, they are probably the most important way to communicate risk in the present context (see further discussion in Abrahamsson & Tehler, 2013: p. 85).

It is also important to point out that the two cases presented in this paper do not focus primarily on the "quality" of each individual function of the risk governance process. This means that we use rather crude ways of analysing whether the functions are fulfilled or not. As a consequence, this only allows us to conclude when the purpose in question is *not* fulfilled, but we cannot use it to reach the opposite conclusion, i.e. that the purpose de facto *is* fulfilled. For example, our analysis of the *Risk identification* function in Case 2 only focuses on the extent to which the various RVA documents describe estimates of scenarios, consequences and associated uncertainties using similar approaches. This analysis allows us to conclude that if the ways used to describe the information are expressed in many different ways, it will be difficult for the *Risk identification* function of the administrative level above to use the material as input. However, we cannot say that if the descriptions in the RVA documents were presented in the same way, it would lead to the fulfilment of the purpose. For example, the output of the function *Risk identification* may be characterised by a lack of detail, or by being too one-sided to provide a useful basis for *Risk analysis*. Such aspects are not included in the analysis here, since we only focus on how information is communicated. While it is important to recognise this potential problem, it is our view that a substantial body of research has focused upon the quality of individual risk governance functions, e.g. through development of new methods and frameworks. For example, in relation to accident investigations, development of new methods has been described as the "holy grail" of systems safety research (Lundberg, Rollenhagen, & Hollnagel, 2010). Such knowledge will be highly useful in future efforts to develop the design perspective of risk governance, and these insights can provide more details on what is required in terms of the output of various functions.

A final area for potential improvement of the design perspective to risk governance involves the possibility to take greater consideration of different framings of risk. In our framework, we have not explicitly addressed the potential challenges related to managing risks in situations where the various stakeholders have diverse, but equally legitimate, framings of the risk in question. In this type of situation, what counts as a risk to one stakeholder may not be seen as such from the viewpoint of another stakeholder (Renn et al., 2011), which in turn may give rise to challenges to managing the risk (see e.g. Cedergren, 2013b). For example, in situations where one stakeholder conducts the identification of risks, while another stakeholder is responsible for the assessment or decision-making over these identified risks, problems may arise due to these different stakeholders' diverse framings, i.e. their different underlying

structures of belief and perception. For this reason, it is important to recognise each stakeholder's framing of the risk in question. This is a potential problem that deserves additional attention in future development of the approach.

CONCLUSIONS

We have introduced and exemplified a conceptual framework for studying risk governance that is influenced by design science. The framework allows micro-level activities, i.e. decisions, actions, production of documents, etc., to be related to macro-level aspects of risk governance. More specifically, the framework allows us to relate the *form*, i.e. how risk in practice is managed, of a risk governance process to the *purpose* of it, i.e. why it exists, by using the risk governance *functions*, i.e. what the system in question does. Moreover, problems of understanding and explaining the characteristics of a specific system (descriptive approach) can be studied within the same framework as problems of improvement (normative approach). Also, problems of determining how well a particular risk governance process is functioning, and of identifying risk governance deficits, can be studied within the framework (evaluative approach). Thus, the suggested framework can be used to achieve an integration of both micro- and macro-level aspects, as well as descriptive and normative approaches.

The usefulness of the framework is exemplified by presenting two analyses of risk governance in two different contexts in Sweden: one related to accident investigation and implementation of the ensuing recommendations in the Swedish railway sector, and one related to the national system for risk and vulnerability assessment. Although the two examples are very different, the findings in both cases indicate a fragmentation of the risk governance processes. In the present framework such fragmentation is detected when studying the functions of the system (descriptive approach), i.e. what does the system do, and comparing them to what the systems needs to do in order to fulfil their purposes (evaluative approach). The fragmentation in the railway example relates to the implementation of risk-reducing measures following accidents, and the fragmentation in the risk and vulnerability assessment example relates to the creation of overviews of risks and vulnerabilities on different administrative levels.

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