Safety and Reliability – Theory and Applications – Čepin & Briš (Eds)
 ISBN 978-1-138-62937-0

User needs for resilience indicators in interconnected critical infrastructures

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ABSTRACT: This paper describes the results of an assessment of user needs in interconnected critical infrastructures. The emphasis is on the needs of governmental agencies responsible for overseeing the risk management practices of enterprises dealing with major accident potential. The case is the Norwegian Directorate for Civil Protection (DSB) and their role in creating oversight and coordination between different stakeholders in areas where several industrial enterprises are located in highly concentrated areas. The risks in such areas includes the potential for domino effects within the area, as well as potentially serious consequences for other critical infrastructures and societal functions. The overall risk may thus be greater than the risks of each individual enterprise. Several industrial actors, different societal sectors and different regulators will be involved in a complex process of governing the individual and accumulated risks. Indicators for both risk and resilience within such an area will therefore require collaboration and exchange of information between several organizations. The main user needs identified are the following:

1. More continuous follow-up of risks. Currently, the main source of information about risk comes from the direct supervision of companies and areas. However, supervisory authorities can only perform a limited number of direct supervisions per year. A set of risk indicators allowing for more continuous monitoring of risks would enable regulators and supervisory authorities to have broader and more updated information about risk.
2. Risk informed selection of topics of supervision. Better indicators would allow for a more informed selection of supervisory activities, thereby ensuring that the emphasis is placed on the most important topics.
3. Risk-based selection of objects for supervision. In order to make the most of the available resources, the supervisory activity should be focused on the companies or areas where the risk is the highest. Indicators providing supervisory authorities with an improved understanding of risk would be an important improvement in this respect.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 700621.

1 INTRODUCTION

1.1 *Problem to be addressed*

This paper describes the results of an assessment of user needs for resilience indicators in interconnected critical infrastructures. The emphasis is on the needs of governmental agencies responsible for overseeing the risk management practices of enterprises dealing with major accident potential.

1.2 *Areas of concentrated industrial activity. — Oslo Harbour (Sydhavna) as an example*

The Oslo Harbour area located at Sydhavna is a condensed area consisting of companies that perform activities that are important for several critical infrastructures and societal functions. According to DSB (2015a), 40% of Norway's total fuel consumption, as well as all airline fuel tanked at Oslo Airport Gardermoen's passes through this area. Moreover, a large fuel depot is also closely connected to the Harbor. This comes in addition to Sydhavna being a large port, with a correspondingly large volume of bulk and cargo logistics. The city center of Oslo is only three kilometers away, and there are roads, railway lines and large sewerage systems in very close vicinity of the harbor.

The Norwegian Directorate for Civil Protection (DSB) are responsible for overseeing the way the different stakeholders at Sydhavna control their own risks, and the way the actors exchange information about risk and coordinate their activities. In general, DSB is responsible for civil protection, covering national, regional and local preparedness and emergency planning, fire and electrical safety, safety in handling and transport of hazardous substances. It is DSB's overall responsibility to keep oversight of risk and vulnerability in Norway. Although DSB will have a direct role in the crisis management of national disasters, their main relation to societal resilience is indirect, through assessing and facilitating the resilience of industrial actors and public sector entities. Condensed industrial areas like Sydhavna are particularly important and challenging, due to the high number of industrial companies located in close proximity to one another. The Sydhavna area contains several enterprises with major accident potential. There is a significant potential for domino effects, as well as the disruption of critical infrastructures and societal functions. This means that the area's accumulated risk may be greater than the sum of the risks of the individual enterprises. Maintaining risk and resilience in this setting will require joint efforts from several industrial actors, different societal sectors and different regulators. Developing indicators for risk and resilience within such an area will therefore require collaboration and exchange of information between several high risk organizations.

2 BACKGROUND

2.1 *The Smart Resilience project*

The Smart Resilience project is an EU project consisting of 20 research partners, led by the European Virtual Institute for Integrated Risk Management (EU-VRi). The starting point of the project is that modern critical infrastructures are becoming increasingly "smarter". Making infrastructures smarter usually means that more use is made of ICT-based solutions in normal operation and use. How these smart critical infrastructures (SCIs) will behave when exposed to extreme threats, such as extreme weather disasters or terrorist attacks has been less addressed. If making existing infrastructure smarter is achieved by making it more complex, would it also make it more vulnerable, or will it increase the ability to anticipate, prepare for, adapt and withstand, respond to, and recover from disturbances? This is the key topic of Smart Resilience (Vollmer et al., 2016). In the report describing the project's initial framework (Vollmer et al., 2016), the way the overarching question will be answered is described through the following steps:

- By identifying existing indicators suitable for assessing resilience of SCIs
- By identifying new smart resilience indicators including those from big data
- By developing, a new advanced resilience assessment methodology based on smart resilience indicators
- By developing an interactive SCI Dashboard tool
- By applying the methodology/tools in eight case studies in different European countries, integrated under one virtual, smart-city-like, European case study. The SCIs considered deal with energy, transportation, health, and water.

The assessment of user needs presented in this paper was an early activity designed to ensure that the project's activities and results were aligned with the needs of key stakeholders within the selected infrastructure sectors.

2.2 *Previous studies of risk and resilience in condenced industrial areas*

Earlier studies of Norwegian industrial areas have shown that while there is a large number of risk assessments from the individual risk owners perspective, there are shortcomings in the overall risk assessment of the area (DSB, 2015a). Lindøe & Kringen (2015) argue that this exposes a gap in existing models of risk governance. Risk governance processes are usually focused on individual enterprises, overlooking important inter organizational issues. Among the challenges identified are multiple and partly conflicting goals, insufficient role clarity, the relationship between risk assessment and public concern over hazards and organizational fragmentation effects in risk governance.

3 THEORY

3.1 *Resilience*

Resilience has been among the most widely discussed topics in safety and reliability research for the last decade or so. There are many strands of research using the concept of resilience, ranging from psychology, sociology, engineering and ecology. Within safety research, Resilience Engineering (RE) has represented a new way of thinking about safety. Traditional risk management has been argued to be based on hindsight and emphasizes error tabulation and calculation of failure probabilities (Dekker et al., 2008). RE shifts the focus from a one-sided focus on errors, to enhancing the ability of organisations to develop capabilities allowing "processes that are robust yet flexible, to monitor and revise risk models, and to use resources proactively in the face of disruptions or ongoing production and economic pressures" (Dekker et al., 2008: 2).

Changing the focus from error avoidance toward adaptation involves a need to understand also how systems are able to absorb and respond to perturbations, including major breakdowns. Errors and disturbances are inevitable, thus we need to understand how systems cope with breakdowns.

The Smart Resilience project takes its starting point in the concept of resilience. As part of the project, reviews of previous resilience research has been undertaken in order to derive a definition to serve as a basis for the project. This definition is a follows:

> *"Resilience of an infrastructure is the ability to anticipate possible adverse scenarios/events (including the new/emerging ones) representing threats and leading to possible disruptions in operations/functionality of the infrastructure, prepare for them, withstand/absorb their impacts, recover from disruptions caused by them and adapt to the changing conditions."*

From this, the following five phases of the resilience cycle have been identified: Understand risks, anticipate/prepare, absorb/withstand, respond/recover, and adapt/learn. This is illustrated in Figure 1.

The main idea behind the SmartResilience project is to develop indicators for each of the phases of resilience that constitute the X-axis of the above figure and apply these indicators to cases of critical infrastructures in smart cities.

3.2 *The challenges of coordination and collaboration—wicked problems*

Creating societal resilience requires the joint efforts of a wide variety of agencies and supervisory authorities, public companies and infrastructure owners. This means that collaboration and coordination among the involved actors is of utmost importance. Previous research has shown that this is not necessarily easily achieved. Creating and improving societal safety and security has been called a "wicked problem", referring to the fact that it does not fit well with the sectoral silos that often characterize public sector bureaucracies (Christensen et al., 2014).

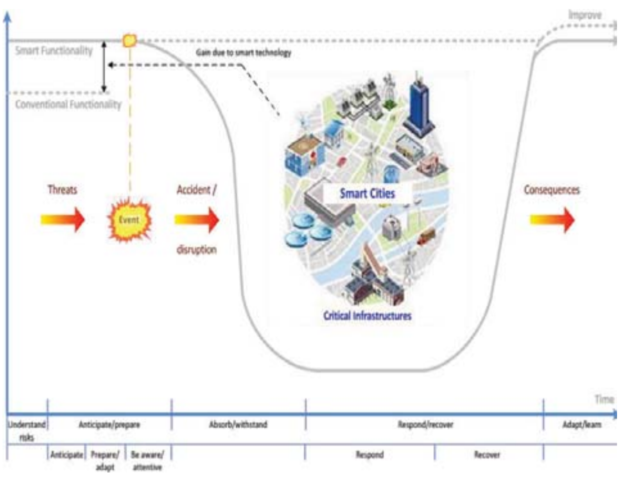

Figure 1. The five resilience phases in the SmartResilience project.

The concept of "wicked problems" emerged more than 40 years ago (Rittel & Webber, 1973) but seems to be increasingly utilized within policy science, public administration, ecology and economics. A key characteristic of a wicked problem is a poor match between problem structure, goal structure and organizational and sectorial structures. Wicked problems transcend sectorial boundaries and cut across several political-administrative levels (Head & Alford, 2014; Christensen et al., 2013). Wicked problems are also intractable in the sense that it is hard to achieve agreement about what the problem really is, what solutions may be, and which adverse effects the implementation of a given solution might generate (Rittel & Webber, 1973).

4 METHODS

The study is based on qualitative methods consisting of semi-structured group interviews with key personnel at DSB and literature reviews. The interviews were guided by the general project interview guide used in the assessment of user needs for resilience indicators in several infrastructures in several European countries. This interview guide was adapted to the context of DSB. As DSB are not responsible for the operation or maintenance of specific infrastructures, the guide was complemented with questions about user needs for indicators that can be used in overseeing the risk and resilience levels of a wide variety of actors. Two researchers conducted the interviews by asking the participants from DSB to discuss their current efforts in assessing risk and resilience, how future development of indicators could assist their work, and what kind of effects such indicators could have for their ability to assess risk and resilience in condensed industrial areas.

5 EMPIRICAL RESULTS

While the concept of resilience is part of DSB's general vocabulary, they have not performed dedicated assessments of resilience. However, they regularly perform supervisions of risk management and emergency preparedness which provide important information about resilience. Their assessments of interconnectivity in concentrated industrial areas are examples of this. Two major assessments on this topic have been on Sydhavna (DSB, 2015a) and Risavika (DSB, 2015b. The main conclusion of the

Sydhavna assessment was that while there was a large number of risk assessments from the individual risk owners perspective, there were serious shortcomings in the overall risk assessment of the area:

> *There is a lack of analyses with comprehensive assessments of all relevant conditions, and which also evaluate the organizational and management-related prerequisites for proper safety in the area. It also appears unclear how the responsibility for conducting comprehensive risk assessments has been understood and followed up by key actors* (DSB, 2015a: 9).

This was interpreted as a shortcoming in the knowledge of the risk situation of the area, as well as pointing to weaknesses in the collaboration and coordination among the companies in the area and the public organizations and supervisory authorities involved.

5.1 *Interviews and activities shedding lights on user needs for resilience indicators*

Three activities of relevance for resilience assessment at Sydhavna and DSBs general responsibilities in resilience assessments were discussed during the interviews:

- The HarbourEx exercise
- A joint supervisory action
- A report on safety in critical infrastructures and societal functions

In the following, we will describe each of these activities, as they are all related to the resilience of critical infrastructures, and the need for resilience indicators.

5.1.1 *HarbourEx15*

HarbourEx15 was s a full-scale rescue and cooperation exercise in April 2015 (DSB, 2015c). It consisted of a combination of scenarios connected to operations in Oslo's main harbour, Sydhavna. The goals for the exercise were to evaluate the mobilization of the emergency organization with a special emphasis on the communication between involved agencies and stakeholders, including communications to the public. The exercise also had an international dimension as it involved personnel from the European Emergency Response Coordination Centre sending a team of experts from Sweden and Austria. More than 3,000 participants were mobilized from over 30 organizations.

HarbourEx15 addressed the following question; would the required resources find each other in dealing with an unexpected and demanding scenario (DSB, 2015c)? The evaluation concluded that there was significant room for improvement in the communication between the actors involved. A main observation was that relevant information about the incident was communicated too late to the public, e.g. how the public should respond to toxic smoke and how people should prepare for possible evacuation. Another observation was the need for strengthening communication lines between governmental agencies and preparation of procedures and agreements that ensure effective communication and coordination between authorities. The EU Civil Protection team (EUCP) should improve their understanding of their own role and at what level their contribution is of benefit. When the affected country's crisis management structures works well, the most beneficial contribution from the EUCP team will be on strategic and administrative level. (DSB, 2015c)

HarbourEx is a case of resilience demonstration in an area with interconnected and complex risk. Evaluations of such exercises can provide direction to the development of indicators by pointing to areas where the system is resilient, and areas where there is need for improvement.

5.1.2 *Joint supervisory action*

Interorganizational cooperation can be an important resource for resilience, particularly where there are dependencies that cross organizational borders. However, coordination of internal control and more comprehensive management of risk in concentrated industrial areas is challenging for both the authorities and the relevant enterprises. One of the follow-up activities of the Sydhavna study was to establish a joint supervisory action, i.e. supervision based on close collaboration between the different supervisory authorities involved with concentrated industrial areas.

One challenge for both DSB and the enterprises is to establish a comprehensive risk landscape for determining when coordination of internal control is required. According to regulations, enterprises should also include external factors in their risk assessments and justify adequately why coordination may not be necessary. However, there is no specific guidance with respect to acceptable level of detail of the risk analyses. The joint supervisory action identified a need for more systematic knowledge about effects and consequences of measures and the development of suitable methodology and appropriate models for including external factors in risk assessments. This includes finding indicators able to provide information about the quality of coordination efforts.

5.1.3 *Report on safety in critical infrastructures and critical societal functions (KIKS)*

One lesson learned from supervisory activities is that there has been a need for a clearer definition of the different critical infrastructures and their corresponding societal functions. Furthermore, a description of how such infrastructures and societal functions may be identified has been lacking. This is information which will be a necessary initial step in developing indicators, and the DSB are in the process of publishing a report describing an approach for assessing the performance of critical infrastructures and societal functions (DSB, 2016). The report should support the Ministry of Justice and Public Security in establishing and maintaining an overview of which functions are critical for societal security in a cross-sectoral perspective. The term critical societal function is defined as those functions that are required to meet the population and society's basic needs such as food, water, heating, security and the like (NOU 2006:6).

In the KIKS project, societal functions are grouped by the way in which they help to meet the population's safety and welfare. The three categories are: 1) Control ability and sovereignty, 2) Population security, and 3) Society functionality. Within each category, "capabilities" are defined which describe the performance level to be maintained by society at all times. The capabilities are based on two premises: 1) a societal function is particularly critical if an interruption of seven days or less will threaten the population's basic needs, and 2) emergency resources may be challenged within that period. Fourteen critical societal functions and associated capabilities have been developed.

Figure 15 shows the hierarchy between critical societal functions and capabilities.

The next step of the KIKS approach is to develop indicators that may measure the performance level of each category. Future development of indicators concerning risk and resilience in Norwegian critical infrastructures should take KIKS categorizations as a starting point. In addition to being a particular user need of DSB, it can also be seen as a case of two more general user needs for development of indicators. The first is the fact that data gathering and indicator development should be a cumulative process starting with making the most of the information that is already there. The second is that a consistent set of indicators that includes information from several enterprises will need to be based on a common framework in order for the information to be transferrable and comparable.

5.2 *User needs—Three general categories of indicators*

The first user need to be satisfied from a governmental agency perspective, is indicators that enables understanding of risk through continuous monitoring. This involves starting the quest for smart resilience indicators by finding more traditional risk indicators. Addressing the other aspects of resilience, i.e. the capacity to adapt, respond and recover is a more long-term need. Three long-term needs for resilience indicators were highlighted:

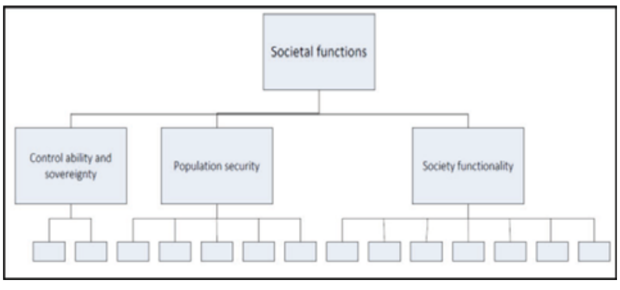

Figure 2. Illustration of the KIKS approach. Adapted from DSB (2012).

1. Indicators describing technical and organizational complexity of supervisory objects. Dealing with interconnectivity requires good system descriptions. Finding a measure of how complicated or complex the involved systems are, is seen as an important part of a future set of resilience indicators. Examples of possible indicators include the number of systems and infrastructures that are connected, the number of owners involved and the extent of organizational changes and changes in ownership.
2. Indicators for collaboration and coordination. Several of DSB's studies (DSB 2015a, 2015b, 2015c) and investigations into national disasters (NOU 2012:14), point to a need for improvement in the collaboration and coordination across organizational and sectoral boundaries. While it is not straightforward to turn information about coordination activities into quantitative indicators, such indicators would be highly valuable for governmental actors with responsibility for supervision of comprehensive risk.
3. Indicators for response capability. Currently, DSB assesses the quality of emergency response plans of supervisory objects. Indicators for response capabilities are needed as supplement to quality indicators. Among the examples mentioned are the frequency of dialogue with the fire department, and the number and type of drills and exercises.

6 DISCUSSION AND RECOMMENDATIONS

The interconnectivity between infrastructures poses a challenge to the development of indicators with respect to interorganizational coordination and exchange of information. A good set of indicators for a critical infrastructure is likely to require the inclusion of information from external actors. This is a user need that is present both within each infrastructure sector, and for users in need of information about comprehensive risk, like DSB.

There are two important points of feedback from the DSB as an end user. Firstly, it is important to have a solid foundation of risk indicators before turning to the larger questions of resilience indicators. In order to develop valid indicators at a governmental level, improvements need to be made in the way data is gathered and processed by risk owners. The KIKS approach represents an important foundation in this respect.

Secondly, indicators need to be able to cover both the inherent, physical risk and risks related to organization and decision-making. Interconnectivity poses a demanding management challenge that needs to be addressed in addition to technical matters.

This study shows a need for better indicators describing the accumulated risk of an area with concentrated industrial activity. Examples given in the interviews include a better overview of the volume of different hazardous substances, the number of incidents related to personal and process safety, the number of deviations from internal control activities and the level of maintenance.

6.1 *Main recommendations*

The main recommendations of the study are:

1. More continuous follow-up of risks. Currently, the main source of information about risk comes from the direct supervision of companies and areas. However, DSB can only perform a limited number of direct supervisions per year. A set of risk indicators allowing for more continuous monitoring of risks would enable DSB to have broader and more updated information about risk. These indicators should be compatible with their existing categorization of critical infrastructures and societal functions.
2. Risk informed selection of topics of supervision. DSB selects different topics for series of supervisory activity. Better indicators would allow for a more informed selection of such topics, thereby ensuring that the emphasis is placed on the most important topics.
3. Risk-based selection of objects for supervision. In order to make the most of the available resources, the supervisory activity should be focused on the companies or areas where the risk and the effect of supervision is the highest. Indicators providing DSB with an improved understanding of risk would be an important improvement in this respect.

There are some challenges in achieving these improvements. DSB would need indicators aggregating information from several actors. This means that DSB will be dependent on the way data is gathered and processed by the actors they are supervising. Companies will, however, have varying capacity in this respect. Larger companies are likely to have sufficient resources and systems in place, while this may not be the case for smaller firms. Another challenge lies in the actors' willingness to share information. Both with regard to competition and security, it may be rational for companies not to share information with the external environment, as long as this is not made mandatory by regulation. In order to meet these challenges, a first step will be to establish a set of guidelines for collecting relevant information, either by DSB or industry forums.

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