Two Applications of Resilience Concepts and Methods: Offshore Installations and Critical Infrastructures[i]

Knut Øien[1]

[1]Senior Scientist, SINTEF, Norway

Contact: Knut.Oien@sintef.no

Keywords: Resilience, Indicators, Major accidents, Early warnings

Resilience development strategies

The main strategy for developing resilience in socio-technical systems, whether this is offshore installations, critical infrastructures, or some other systems, is to demonstrate practical usefulness of resilience approaches for the relevant stakeholders, starting with simple concepts, models and methods. After all, all definitions, concepts and models are simplified representations of reality, no matter the complexity of the representation. It is recommended not to make the starting-point too complicated.

Thus, the strategies used in the two applications presented in this paper have been to develop pragmatic, practical and easy to understand/communicate approaches. The approaches are further tailored to the relevant stakeholders, and they are participatory approaches where the stakeholders take an active part in defining the issues that are important for each resilience dimension, and in defining the indicators measuring the issues.

The resilience dimensions provide a fixed frame, whereas the issues important for each dimension and the indicators to measure these issues are provisional (candidates). They will be reviewed and evaluated by stakeholders (e.g. users and domain experts), and may be adjusted and new issues and indicators added.

Indicators and measurements

Both applications utilize indicators, either as early warnings for potential events or as measures of resilience. The first application focuses on trends in the indicator values, which may indicate a drift towards potential events, whereas the second application uses indicators as a means to measure resilience.

Measurement of resilience using indicators provides status on the various phases/dimensions in a semi-quantitative manner expressed as a level on a scale. It is not about millimetre precision, but an indication of the level at which resilience is obtained in each phase. It is an indirect measure of resilience that does not require actual event data (which is often rare and hard to obtain, especially since we also need to cope with surprises). The indicators do not provide an exact measurement of

---

[i] This paper is part of the IRGC Resource Guide on Resilience, available at: https://www.irgc.org/risk-governance/resilience/. Please cite like a book chapter including the following information: IRGC (2016). Resource Guide on Resilience. Lausanne: EPFL International Risk Governance Center. *v29-07-2016*

e.g. the shape of the functionality curve (cf. Figure 2). The functionality curve itself is only used as a conceptual model, not as an operational model.

A word of caution when it comes to indicators: An indicator is "a measurable/operational variable that can be used to describe the condition of a broader phenomenon or aspect of reality" (Øien, Utne & Herrera, 2011). This aspect of reality – also termed the theoretical variable – may be risk factors, resilience issues, etc. We cannot measure these directly; instead, we need an operational definition of the factor/issue that represents the theoretical variable. This operational variable is what we denote an indicator. The indicator will typically be described as a number, ratio, score on some scale, or similar. Without this type of specification/operationalization, we are left with just a theoretical factor or issue. Unfortunately, what is often referred to as indicators, also in the resilience literature, are just factors or issues. They are not made operational, which means that they are not indicators, even if they are presented as such.

Two applications – different definitions and concepts

The first application is a methodology for the establishment of early warning indicators for offshore oil and gas installations, which was evaluated/demonstrated against the Deepwater Horizon drilling rig accident in the Gulf of Mexico in 2010. The second application is a preliminary approach for resilience assessment of critical infrastructures.

The two definitions used are:

Definition 1: *Resilience refers to the capacity of recognizing, adapting to, and coping with the unexpected* (Woods, 2006).

Definition 2: *Resilience of an infrastructure is the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruption.*[ii]

It may be questioned to what extent the definition in itself is important, since definitions by nature comprise condensed and thereby limited amount of information. In the first application, a concept of resilience was developed that only partly reflected the definition. It was the concept, and the methodology developed based on this concept, that was important for this application. The two applications are described below, focusing on the concepts of resilience used.

Application 1 – Evaluation of methodology for early warning indicators using the Deepwater Horizon accident

The methodology, termed Resilience-based Early Warning Indicators (REWI) method, is described in Øien, Massaiu and Tinmannsvik (2012), and the evaluation using the Deepwater Horizon accident is described in Øien and Nielsen (2012).

The fundamental attributes/dimensions of resilience covered by the REWI method are called contributing success factors (CSFs) and are risk understanding, anticipation, attention, response, robustness, resourcefulness/rapidity, decision support and redundancy. For each CSF, the REWI method defines a set of general issues contributing to the fulfilment of the goals of the CSF. Measurable indicators are developed for the issues.

[ii] This is an adaptation of a definition proposed by the National Academy of Sciences (2012): *the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events*.

The CSFs are based on key literature sources (e.g., Woods, 2006; Woods & Wreathall, 2003; Tierney, 2003), and was tested in an empirical study on the successful recovery of high-risk incidents (Størseth, Tinmannsvik, & Øien, 2009). The empirical study supported the selected set of CSFs, which are shown in Figure 1. The CSFs represent an operationalization of the concept of resilience. Figure 1 also includes questions to enhance the understanding of the CSFs.

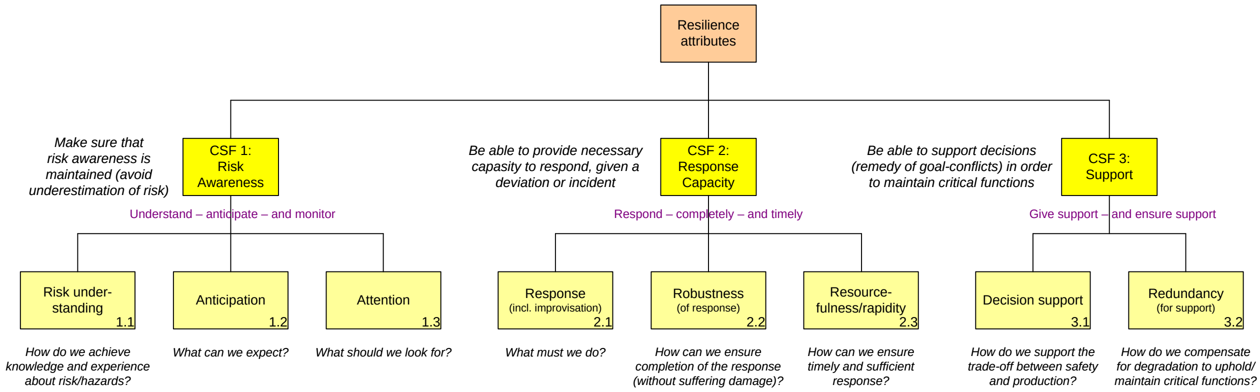

Figure 1: The concept of resilience based on Contributing Success Factors (CSFs)

The REWI method was applied to analyse the causes and factors that led to the DWH accident. The mapping of the predefined REWI issues to the DWH accident causes showed that relevant early warnings could have been provided, and the accident might have been prevented, if the respective issues had been followed-up by the use of relevant indicators. This depends of course not only on relevant early warnings, but also on adequate response to the signals given. Details of the evaluation are found in Øien and Nielsen (2012).

Application 2 – Resilience assessment of critical infrastructures

Resilience assessment of critical infrastructures is included in the scope of the EU H2020 project SmartResilience (Smart Resilience Indicators for Smart Critical Infrastructures)[iii]. It uses the critical infrastructure system functionality curve (Linkov et al., 2014) as a starting point, but adds additional resilience dimensions as phases, as shown in the timeline in Figure 2.

[iii] http://www.smartresilience.eu-vri.eu/ will provide results and deliverables from the project (in 2016-2019).

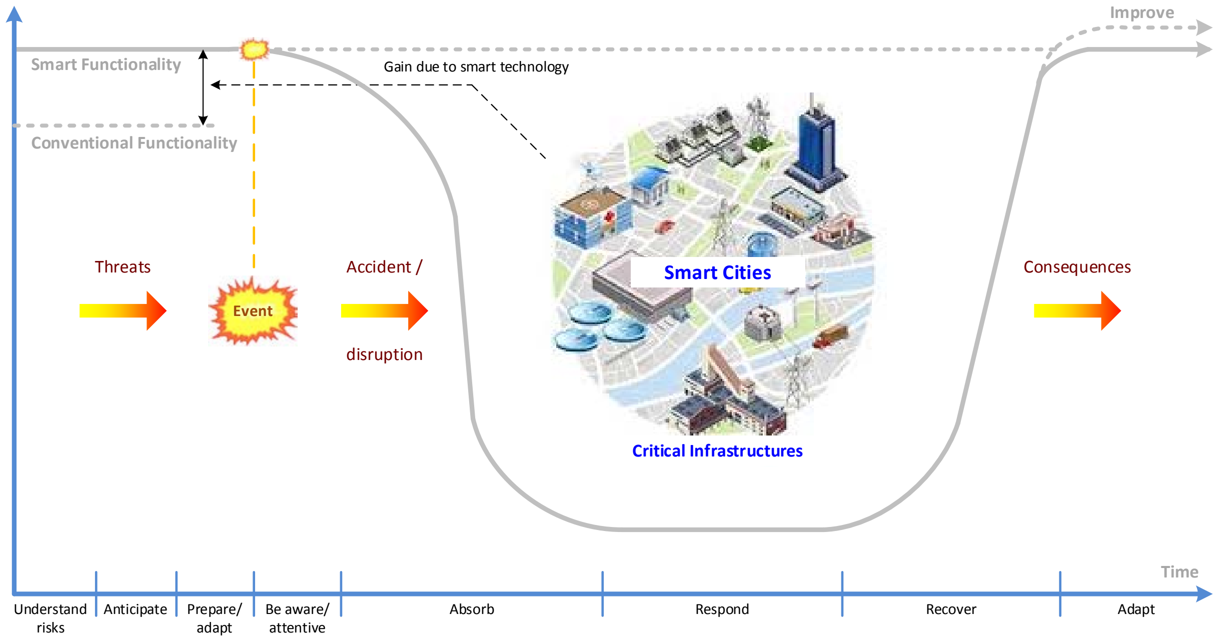

Figure 2: Preliminary concept of resilience based on the system functionality curve

The curve itself could be studied in detail, e.g. determining the slope of the absorption curve and the speed of recovery; however, the main approach in SmartResilience is to assess the resilience dimensions indirectly using indicators. Similarly as in the REWI method, there will be a layer of "issues" between the resilience dimensions and the indicators.

A special feature of the SmartResilience project is the focus on increased functionality enabled by smart technology providing smart critical infrastructure. This gain in functionality also represents an emerging threat, since the smart technology may increase the vulnerability of the critical infrastructures.

The resilience dimensions manifested as phases in the functionality-time curve is sequential; whereas the resilience dimensions manifested as contributing success factors in the REWI method is non-sequential, (e.g. decision support is provided at several stages). Thus, the concepts are different and adapted to the specific applications. However, notice that risk understanding (risk picture/landscape) is the starting phase in both applications, linking risk and resilience.

A common feature of both applications is the use of indicators – resilience indicators: in the first application to provide early warnings and in the second application to provide a measure of resilience (for each issue, each phase/dimension, and each critical infrastructure).

The main differences foreseen in the SmartResilience approach to resilience assessment of critical infrastructures, compared with previous and on-going approaches, are the level of issues between the resilience dimensions and the indicators, and the stakeholder participation in defining and adjusting the (candidate) issues and indicators.

Resilience purpose and preference

Quite a lot of effort goes into justifying resilience or resilience management as an additional strategy to risk management, but mainly on a conceptual level (e.g. Linkov et al., 2014). Here, the purpose of resilience is discussed for the two specific applications: early warnings and assessment of resilience.

Different types of indicators (e.g. resilience-based, risk-based, performance-based, and incident-based) have different pros and cons (Øien, 2013). The purpose of using resilience-based indicators, instead of risk-based indicators, for early warnings is that development of resilience-based indicators is e.g. more relevant as early warnings (cover issues early in the casual chain), less resource intensive, and has generally a broader coverage. They may also focus on positive signs and signals. A drawback is that it is less easy to determine risk relevance/importance of resilience-based indicators.

The purpose of assessing resilience, not instead of, but in addition to risk, is that some of the phases are less emphasised in traditional risk analysis/assessment/management, e.g. the recovery and adaptation phases, whereas in our resilience assessment all phases (dimensions) are assessed.

In the two applications: early warnings and assessment of phases in critical infrastructure protection, a resilience approach is considered as better suited compared to traditional risk management, since it better covers all the phases.

Annotated Bibliography

Linkov, I., Bridges, T., Creutzig, F., Decker, J., Fox-Lent, C., Kröger, W., . . . Thiel-Clemen, T. (2014). Changing the Resilience Paradigm. *Nature Climate Change 4*(6):407-9.
This source introduces the functionality curve and the temporal description of resilience dimensions as phases. The original four phases are used as a starting-point in this paper, but extended to eight phases.

National Research Council Disaster Resilience: *A National Imperative* (The National Academies Press, 2012).
This source provides the definition, which is used as a basis for the original four phases of resilience in the functionality curve.

SmartResilience (http://www.smartresilience.eu-vri.eu/). This source provides results and deliverables from the project.

Størseth, F., Tinmannsvik, R.K., & Øien, K. (2009). Building safety by resilient organization – a case-specific approach, Paper at the *European Safety and Reliability Association Annual Conference (ESREL)*, 7 – 10 September 2009, Prague, Czech Republic.
This source provides information about the concept of resilience used in REWI method for early warning indicators, in particular how the CSFs were derived.

Tierney, K. J. (2003). *Conceptualizing and Measuring Organizational and Community Resilience: Lessons from the Emergency Response Following the September 11, 2001, Attack on the World Trade Center*. Disaster Research Center, Preliminary Papers, No. 329.
This source provides input to the CSF concept of resilience used in the REWI method.

Woods, D.D. (2006). *Essential Characteristics of Resilience*, In: N. Leveson, E. Hollnagel, and D.D. Woods, Resilience engineering: concepts and precepts, Ashgate, Aldershot, pp 22–34.
This source provides input to the CSF concept of resilience used in the REWI method.

Woods, D.D., & Wreathall, J. (2003). *Managing Risk Proactively: The Emergence of Resilience Engineering*, Columbus, Ohio University.
This source provides input to the CSF concept of resilience used in the REWI method.

Øien, K. (2013). Remote operation in environmentally sensitive areas: development of early warning indicators, *Journal of Risk Research 16*(3-4) 323-336.
This source describes pros and cons of various types of indicators, including resilience indicators.

Øien, K., Massaiu, S., & Tinmannsvik, R. K. (2012). *Guideline for implementing the REWI method; Resilience-based Early Warning Indicators*, SINTEF report A22026, SINTEF Technology and Society.
This source describes the REWI method for development of early warning indicators.

Øien, K., Nielsen, L. (2012). Proactive Resilience-Based Indicators: The Case of the Deepwater Horizon Accident. *SPE / APPEA International Conference on Health, Safety and Environment in Oil & Gas Exploration and Production*, 11-13 September, Perth, Australia.
This source evaluates the early warning indicators developed from the REWI method using the Deepwater Horizon accident as a demonstration case.

Øien, K., Utne, I. B., & Herrera, I. A. (2011). Building safety indicators. Part 1 – theoretical foundation. *Safety Science 49*(2) 148–61.
This source provides fundamental information on indicators, including definitions and operationalization.