

# The Importance of Resilience-Based Strategies in Risk Analysis, and Vice Versa

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As societies and economies continue to be subject to system disruptions and rapidly changing conditions, it is essential to implement resilience strategies that allow these systems to maintain functionality and effectively recover from disruptions. One critical component of an effective resilience strategy is the assessment of risk. Vice versa, there is a need for resilience-based strategies in risk analysis and management, as risk assessments have limitations in dealing with uncertainties, potential surprises and the unforeseen. In this paper we review and discuss these interactions and dependencies between resilience and risk. We outline how recent advancements in risk and resilience science have created a new platform for merging both quantitative and qualitative assessments. These advancements relate to the way risk and resilience are conceptualized and characterized, but also how we should in general confront uncertainties.

## Introduction

In the following we use the term ‘risk analysis’ in agreement with the long tradition of Society for Risk Analysis (SRA) to include the areas of risk assessment, risk characterisation, risk communication, risk management, and policy relating to risk (SRA, 2015). To further simplify the nomenclature, a similar definition is used for resilience: ‘resilience analysis’ includes the areas of resilience assessment, resilience characterization, resilience communication, resilience management, and policy relating to resilience.

The fields of risk analysis and resilience analysis are essential for enabling societies and economies to effectively manage system disruptions. Research in both fields have made significant advancements in recent years, allowing for organizations to concurrently manage both risk and resilience for applications like infrastructure, cyber-systems and commerce (Alderson, Brown, & Carlyle, 2015; Linkov et al., 2013; Park, Seager, Rao, Convertino, & Linkov, 2013). Given the importance of each distinct field, there is a need to develop an overall understanding of the role of risk assessment and management in resilience strategies, and the role of resilience strategies in the assessment and management of risk.

The study of resilience seeks to address how to enable a system to sustain and restore (and even improve) its functionality following a change in the condition of the system (disruption, threat,

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opportunity - referred to as an event). As discussed in the literature (see Aven, 2017a) the resilience management (engineering) can, in principle, be conducted without considering potential events and risk. For example, adding redundancy in the system may be an effective resilience management strategy, and it does not need assessment of specific events and associated risk, to be implemented. A system manager would not need to know what type of events can occur and express their likelihoods as required in traditional risk assessments. In cases with large uncertainties related to what type of events that will occur, this is important because risk assessments then are not able to produce reliable probability estimates. Resilience strategies are of special relevance for complex systems, where it is acknowledged that unforeseen events or surprises will occur (Aven & Ylönen, 2018). Resilience analysis and management are especially suitable for confronting unknown and uncertain types of events, and both quantitative and semi-quantitative approaches for resilience assessment have been studied in the literature (see Linkov et al., 2013; Fox-Lent, Bates, & Linkov, 2015; Ganin et al., 2016; Gisladdottir, Ganin, Keisler, Kepner, & Linkov, 2017; Gao, Barzel, & Barabási, 2016). Traditional risk assessment is not a part of the methodology used in these studies.

There have been recent calls for a shift from risk to resilience, to a large extent motivated by the need for meeting the effects of climate change, by many organizations, scientists and leaders, including the former Secretary-General of the United Nations, Ban Ki-moon (UNISDR, 2015). These calls raise some questions. Are they arguing that the resilience strategy should be highlighted at the expense of the contemporary frameworks for handling risk? How do the calls acknowledge the fact that current risk science considers resilience analysis and management as an important strategy for managing risk? Also, arguments have been presented showing that risk considerations can provide useful input to the resilience analysis and management (Aven, 2017a). There seems to be a need for clarifying the interactions and dependencies between these two fields, and this is exactly what this paper seeks to obtain. It does this by first discussing how resilience-based strategies are essential for risk analysis. Then risk is shown to be an important factor in resilience analysis and management. The final section extends the discussion to a performance setting. The work summarizes and extends discussions in recent papers on the topic, including Aven (2017a) and Thekdi and Aven (2016).

### **Resilience-based strategies in risk analysis**

Traditionally risk analysis has been linked to risk assessment and the use of this tool to inform decision makers (see e.g., Park et al., 2013). However, broader approaches have been developed, with many founded on risk governance frameworks (IRGC, 2005; Renn, 2008). What characterizes these approaches and frameworks is an acknowledgement of the need for seeing beyond risk assessments in order to adequately handle risk. Three main categories of strategies for handling risk are identified, i) risk-assessment informed, ii) cautionary and precautionary approaches, highlighting robustness and resilience, and iii) dialogue and participation (Renn, 2008; Aven, 2017a; SRA, 2017). The categories ii) and iii) are justified by the limitations of the risk assessment approach, in particular for being able to deal with uncertainties and potential surprises. Resilience is seen as a pillar of risk management and risk analysis as defined above.

The cautionary/precautionary (robustness/resilience) strategy includes features such as constant monitoring, containment, and research to increase knowledge and the development of substitutes. Specifically, resilience captures measures such as strengthening of immune systems, diversification and flexible response options (Renn, 2008). In the discursive strategy, measures are implemented to

build confidence and trustworthiness, through the clarification of facts, reduction of uncertainties, involvement of affected people, deliberation and accountability (Renn, 2008).

The precautionary principle is interpreted as stating that in case of a potential for severe consequences and scientific uncertainties about the consequences of an activity, protective measures should be taken to reduce risks (Aven & Renn, 2018). The cautionary principle extends the precautionary principle, stating that if the consequences of an activity could be serious and subject to uncertainties, then cautionary measures should be taken or the activity should not be carried out (Aven & Renn, 2018). While the precautionary principle is used in cases of scientific uncertainties, the cautionary principle is used for all types of uncertainties and ambiguities.

Risk analysis frameworks building on these three strategies are founded on broad perspectives on risk, acknowledging that risk is more than calculated probabilities and risk metrics. In line with recommendations of the Society for Risk Analysis (SRA, 2015), risk has two main features: the consequences (C) of the future activity considered – for example the operation of a manufacturing facility or the life in a country – and related uncertainties (U). The consequences are often seen in relation to some reference values (planned values, objectives, present state, etc.) and are with respect to something that humans value. There is always a potential for some negative outcomes. While historic study of risk has focused on negative or undesirable consequences, the SRA framework is general and allows for both negative and positive outcomes. Risk defined in this way makes a clear distinction between the concept (here risk) and how this concept is described, measured or characterised, in line with measurement theory. A probability distribution of the number of fatalities, as a result of the activity, is an example of such a risk characterisation. The ways risk can be characterised are many, but in its broadest sense, it captures (C', Q, K), where C' are some specified consequences (for example the number of fatalities), Q a measure or description of uncertainty (for example probability and associated judgments of the strength of knowledge supporting the probabilities) and K the knowledge supporting P (Aven, 2017b).

Often the consequences explicitly refer to events A that can occur leading to some effects. Resilience is understood as the ability of the studied system to maintain functionality and effectively recover given that one or more events A occur, whether these events are known or not. Of special importance is the case of planning for resilience of the system for events A, that are not identified in C'. We will return to the resilience concept in the next section.

### **Risk considerations supporting resilience analysis and management**

As mentioned in the introduction, resilience can to some degree be analyzed and managed without considering risk. We can improve the immune system by proper training, without really thinking about risk. However, further reflections would quickly make us realize that risk considerations are needed in relation to resilience analysis, for two notable reasons (Aven, 2017a):

Firstly, risk analysis would supplement resilience analysis by addressing the potential occurrences of events. Through such analysis, new insights may be gained, for example, unknown and potentially surprising types of events could be identified, and new “cause-effect” relationships can be revealed. Concrete and more effective measures can then be developed to meet these events. By studying why certain infections occur, more effective measures can be developed than if the focus is limited to how to make the body withstand infections in general. Medicine, to a large extent, focuses on

performing risk analysis related to known and unknown types of threats. It would be an extremely poor policy to lean on resilience-based strategies alone.

Secondly, risk analysis would supplement resilience analysis in order to obtain more effective use of resources. In practice there are always resource limitations and that means that organizations must prioritize those limited resources to decide how and where to improve resilience. There could be many areas in which the resilience can be improved, but which should be selected and given weight? Many resilience metrics exist but what events will in fact occur? Say that a system can be subject to two types of events,  $A_1$  and  $A_2$ . The system is resilient in relation to event  $A_1$  but not to  $A_2$ . Now suppose  $A_2$  will occur with a probability of 0.000001% and  $A_1$  with a probability 0.999999%. Suppose a specific arrangement would significantly improve the resilience with respect to event  $A_2$ , but its effect on risk (interpreted in a wide sense) is marginal. The arrangement could still be justified, but some types of consideration of risk seem useful, also in the case that we have difficulties in assessing likelihoods and being accurate on what type of events that will occur, as we always need to make prioritizations. The question is rather how we can make these considerations of risk informative.

Different types of risk assessment methods can be used for the purpose of supplementing the resilience analysis. They are typically not traditional quantitative risk assessments searching for accurate probability estimates, but broad qualitative assessments of events, recovery (return to the normal condition or state) and uncertainties (see Aven, 2017a). The objectives of these assessments can be to obtain insights by:

- i. Making a judgement of the type of events that can occur, what we know and do not know (highlighting key assumptions and justified beliefs).
- ii. Making a distinction between known types of events, unknown types of events, and surprising events.
- iii. Assessing the probability for these types of events whenever found meaningful (using subjective probabilities or subjective interval probabilities).
- iv. Assessing the strength of knowledge supporting these judgements. How can the knowledge be strengthened?
- v. Conducting assessments to reveal unknown and surprising events.

As a third and final way risk considerations can support resilience analysis, think of the objective of recovering or sustaining functionality and performance, or in other words, returning to the normal state following the event (disruption). Using the general risk set-up introduced in the previous section, the consequences  $C$  can be viewed as a deviation from this objective. The resilience is studied for fixed events  $A$ , but conceptually, the problem faced is similar to the one considered above with risk understood as  $(C,U|A)$  and a description or characterisation of the form  $(C',Q,K|A)$ , where the term " $|A$ " is to be read as 'given the occurrence of  $A$ '. If a system is not resilient against a specific event  $A$  but this event is improbable, the system can still be considered resilient.

## Discussion

The above discussion has shown that risk and resilience analysis are closely integrated. From the analysis in Section 2 we schematically can write

$$\begin{aligned} \text{Risk} = (A,C,U) &= (A,U) + (C,U|A) \\ &= \text{“occurrence of events, and associated uncertainties”} + \text{resilience,} \end{aligned}$$

clearly showing that the resilience is a part of the risk concept, and hence resilience analysis can be seen as an element of risk analysis. More precisely,  $(C,U|A)$  is to be understood as the ‘resilience-induced conditional risk’ or ‘lack of resilience-induced conditional risk’, given the occurrence of A. The symbol ‘+’ is here not to be interpreted as a sum, as in mathematics, but as a symbol for combining the two elements. The previous section argues that risk considerations are needed in relation to resilience analysis in different ways. Representing resilience by  $(C,U|A)$ , the uncertainties related to which events A that will occur need to be addressed in some way in order to meaningfully conduct the resilience analysis. Current perspectives on how to characterise risk, such as  $(C',Q,K)$ , are also applicable for the conditional case of resilience, leading to resilience characterizations of the form  $(C',Q,K|A)$ .

The integration is clearly observed when extending the discussion to performance-based type of frameworks, as in Thekdi and Aven (2016). The set-up can briefly be described as follows:

The future performance of a system is affected by events (stressors, opportunities), which can lead to performance output O above or below a reference level (expressing for example a planned value, a goal or the current state). There are uncertainties associated with both the occurrence of these events and the actual performance output. Similar to the study of risk, the performance-related uncertainties are assessed using some measure Q, typically covering probability (or imprecise probability) and associated strength of knowledge judgments. The background knowledge K, on which Q is based, constitutes an element of the performance characterization. The resilience management is focused on the task of recovering or sustaining functionality and performance, given an event, and is thus an important element of the performance management.

Traditionally, performance management has focused on the management of opportunity, whereas risk management has put emphasis on the study of missed or lost opportunity. The broader framework outlined above allows for a more holistic perspective which allows for resilience and risk analysis to be viewed as complementary activities aimed at managing system performance.

There is need for further work linking resilience-based strategies in risk analysis and management. The resilience-based approach allows decision-makers to put larger emphasis on managing system performance to confront potential surprises and unforeseen events, but needs always to be seen in relation to risk as argued for above. At a more practical level, there is need to integrate resilience and risk analysis and management into organizational processes, such as enterprise risk management procedures.

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