Resilience, Stability and Requisite Interpretation in Accident Investigations

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Abstract. The concept of 'resilience' is often absent in accident investigations, most likely because one of the central notions in resilience, 'requisite imagination', seems to be of limited utility when used in hindsight. In this paper we argue that requisite imagination is often a mirage, and that its false promise may well be based on treating stability and resilience as one unified concept. It is important to see the distinction between recommendations from accident investigations that aim at maintaining the ability to respond to known disturbances, (stability) and recommendations aimed at increasing the ability to cope with irregular and unexampled events (resilience). Instead of attempting to maximize resilience and stability at the same time, it may be more fruitful to try to balance these properties of a system. Thus, in accident investigation a safety perspective should include both traditional stability-enhancing perspectives as well as a resilience perspective.

1 INTRODUCTION

The concept of 'resilience' is often absent in accident investigations, most likely because one of the central notions in resilience, 'requisite imagination', seems to be of limited utility when used in hindsight. In order to understand what resilience is, or means, we have examined the definition in the main source that we have identified; Holling's (1973) paper on resilience and stability of ecological systems. In this paper we argue that requisite imagination is often a mirage, and that its false promise may well be based on treating stability and resilience as unified perspectives. By neglecting the distinction between recommendations from accident investigations that aim at maintaining the ability to respond to known disturbance, (stability) and recommendations aimed at increasing the ability to cope with irregular and unexampled events (resilience), the resilience concept becomes diluted. Instead of attempting to maximize resilience and stability at the same time, it may be more fruitful to try to balance these properties of a system. In this paper we examine the concept of resilience engineering in relation to accident models and accident investigation.

2 RESILIENCE AND STABILITY

The term resilience, according to our knowledge, originates from the paper “Resilience and Stability of Ecological Systems” by Holling (1973). In the paper, Holling discusses perspectives on ecological systems and questions the, at the time, common use of mathematical models from the engineering sciences in analysis of the survivability of animal populations. A common approach in the field of ecology was the assumption of stability, meaning that systems that could recover to a state of equilibrium after a disturbance would survive in the long run. Instead, Holling presented the idea of resilience, stating that the variability of most actual environments is high, and that stable systems in many cases actually are more vulnerable than unstable ones.

“Traditionally, discussion and analysis of stability has essentially equated stability to systems behavior. In ecology, at least, this has lead to confusion since, in mathematical analyses, stability has tended to assume definitions that relate to conditions very near equilibrium points. This is a simple convenience dictated by the enormous analytical difficulties of treating the behavior of nonlinear systems at some distance from equilibrium. On the other hand, more general treatments have touched on questions of persistence and the probability of extinction, defining these measures of stability as well. To avoid this confusion I propose that the behavior of ecological systems could well be defined by two distinct properties: resilience and stability.

Resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist. In this definition resilience is the property of the system and persistence or probability of extinction the result. Stability, on the other hand, is the ability of a system to return to an equilibrium state after a temporary disturbance. The more rapidly it return, and with the least fluctuation, the more stable it is.”

(Holling, 1973, p. 17)

In our opinion, some researchers interested in the field of safety/resilience engineering seem to confuse the notion of resilience and stability, actually discussing what Holling refers to as stability rather than resilience, since, as Holling states “With this definition in mind a system can be very resilient and still fluctuate greatly, i.e. have low stability” (Holling, 1973, p. 17). From Hollings perspective, the history, or in our case, the experience, of a system is an important determinate for how resilient it can be. He exemplifies by showing that species that exist in stable climates with little interaction with other species tend to become very stable, but have low resilience. Species acting in uncertain, dynamic environments are often subject to great instability in terms of population, but the species as such may be resilient and survive over very long time periods.

Holling motivates the study of resilience rather than stability by stating:

“A management approach based on resilience, on the other hand, would emphasize the need to keep options open, the need to view events in a regional rather than local context, and the need to emphasize heterogeneity. Flowing from this would be not the presumption of sufficient knowledge, but the recognition of our ignorance; not the assumption that future events are expected, but that they will be unexpected. The resilience framework can accommodate this shift of perspective, for it does not require a precise capacity to predict the future, but only a qualitative capacity to devise systems that can absorb and accommodate future events in whatever unexpected form they may take."

(Holling, 1973, p. 21)

A lesson learned from Hollings original ideas is that systems not only should be designed for stability, even if this often is desired, especially in production systems, but also that a sole focus on resilience hardly is appropriate either. Instead, we need a balance between resilience and stability. Stability is needed to cope with expected disturbances, while resilience is needed in order to survive irregular and unexampled events. A resilient system does not have to make a "perfect recovery" from a disturbance, but rather accept that it can be temporarily disabled as long as it survives in a longer perspective.

This also leads us to the fundamental problem of designing 'safe', or 'stable' systems; increasing stability to one kind of event, might decrease stability in relation to another kind of event. It is impossible to prevent some events, like Tsunamis, or prevent all events of some kinds like forest fires or car accidents. Instead the focus should be on the reactions to the events, and on the general ability to handle consequences to harmful events. In addition to requisite imagination, practice can be needed to handle unusual events or new configurations for events. That is, to get some practice, skills, and knowledge of other individuals, while being outside the loop. In order to balance between stability and resilience, issues of stability also need to be considered. Traditional responses like barriers may be needed. The responses may vary according to the kind of event.

2.1 Accident models and their relation to resilience and stability

Hollnagel (2006) describes three kinds of common accident models that underlie most forms of accident analysis, the simple linear model, the complex linear model and the systemic non-linear model. A simple linear model focuses on cause-effect in event chains. A common example of a simple linear model is the domino model. In the domino model, according to Hollnagel, a safe system spaces pieces far apart, or have pieces that cannot fall. To our knowledge, the domino model was first described in 1920, although without explicitly talking about domino bricks.

"Doubtless every accident is, in fact, the outcome of a long train of events. If only complete information were available, it should be possible to trace any accident to some remote initiating causes – ultimately, in many cases, to some failure of insight or foresight on the part of some human agent."

(U. S. Bur. Labor Statistics Bull. 276 , 1920, cited in Heinrich, 1931, p 41)

A complex linear model focuses on combinations of unsafe acts and latent conditions (Hollnagel, 2004). It focuses attention on barriers and observations of indicators of deviation (monitoring). In the complex linear model, a safe system can withstand erosion caused by latent conditions and maintain barriers (Hollnagel, 2006). Recommendations from these two accident model types would, according to the distinction made by Holling (1973) above, increase the stability of the system.

A non-linear model focuses on normal events, in the present system, variations in these, and how these events and variations can combine and give rise to negative events (see for example the functional resonance model) (FRAM), Hollnagel, (2004); or systemic accident models. From a systemic perspective, resilience is described as “an organization’s ability to adjust to harmful influences rather than to shun or resist them.” (Hollnagel, 2006, p. 14). This corresponds the definition proposed by Woods & Cook (2006, p. 69) ”Resilience in particular is concerned with understanding how well the system adapts and to what range or sources of variation”.

2.2 Balancing resilience and stability

When reviewing the three kinds of threats described by Westrum (2006), the *regular event*, the *irregular event*, and the *unexampled event*, these also seem to match the division between resilience and stability. Whereas for the regular event, fine-tuning (for instance improving on barriers) re-defining the stable conditions for that system. For regular events, the recommendation might not be to alter the resilience-maintaining process, but rather to use it to fine-tune the system to re-attain stability. Moving from that to irregular and unexampled events, the demand for resilience increases (see figure 1.)

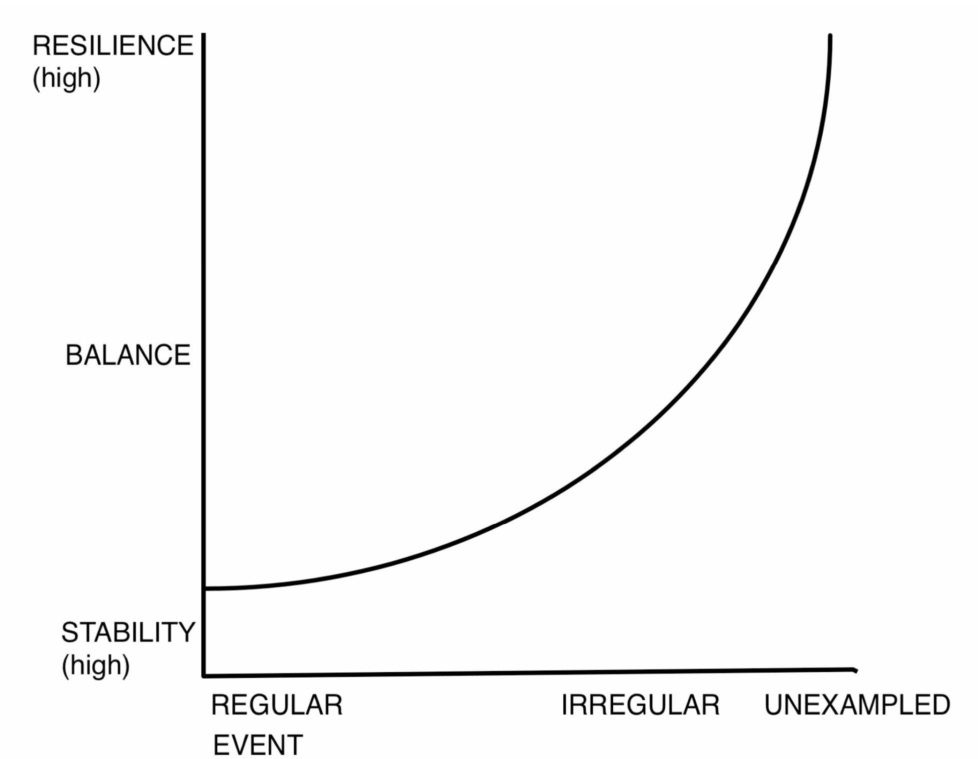

Fig. 1. An outline for the relation between the need for resilience or stability in the face of different types of unwanted events.

To achieve safe performance, this means that we should focus on the balance between stability and resilience rather than focusing solely on resilience. Instead of trying to maintain stability in the face of these irregular or unexampled events, the system instead responds by changing itself. In the irregular event, adaptation, a different use than normal of existing resources, might suffice. In that case, the recommendations might be to increase the ability to adapt, for instance by training personnel. Recommendations might also aim at making the system more stable, should that event ever recur, perhaps by making the temporary process resulting from the adaptation a permanent part of the system. Thus, in the safety-maintaining process there is focus both on resilience and stability. For the unexampled event, there might be a need to reconfigure the system more drastically, by hiring new staff, re-organizing work, creating new tools, and so forth. In that case, resilience comes in the form of accepting the need for a total reconfiguration, thus not adaptation, but a complete change with the purpose of surviving rather than maintaining. If the changes are done without the ability to make new changes in the face of a new unexampled event, then the changes were made to achieve stability in the face of a specific threat, not to achieve resilience against threats in general. If we also consider the costs of being resilient in this sense, we see the risk that using resources to be resilient in the face of one crisis, might use them up, making the system vulnerable to the next, different, crisis, rather than increasing safety in the system. This is in line with how the problem is described by Westrum (2006, p. 65) ”A resilient organization under Situation I will not necessarily be resilient under Situation III. ”.

2.3 Requisite interpretation

As an example of how resilience differs from stability, we can see how seemingly stable organizations may become paralyzed by unexampled events. As an example, in the Swedish response to the Asian tsunami, key actors were unable to imagine the event, even after it has occurred, and after evidence of it has started to flow into the organization. This is in line with a quote stated by the famous Swedish comedian/writer Tage Danielsson:

“I mean, before Harrisburg, it was utterly unlikely that what happened in Harrisburg would happen, but as soon as it happened, the probability increased to no less than 100 percent so it was almost true that it had happened.

But just almost true. That’s the strange thing here. It is like if you think that what happened in Harrisburg was so incredibly unlikely so that in fact it probably has not happened.”

(Danielsson, 1992, p 346, our translation from Swedish)

An accident is an excellent source of requisite imagination of future events, since it easier to imagine a future event similar to one that has just occurred, than to imagine one that has never happened. However, ‘complete’ requisite imagination of unexampled events is most likely a mirage, a wish for something we cannot have. What we instead could have, is requisite interpretation, the ability to see the facts of an accident or disaster and actually accept that it happened and respond properly. In many cases that is to start a process of adaptation and reconfiguration, but it may also be a process of total reconfiguration of a system. When doing that, it is vital to have had requisite imagination to the extent that some preparations for the unexpected have been made. Such preparations could, for instance, be to have field hospitals and trained personnel, to use in a remote disaster – without knowing exactly what will happen, or when, or even that it would happen at all.

2.4 The Matryoshka problem of maintaining safe performance

When talking about resilience and stability, it can be useful to separate the primary system which is to be resilient or stable, from the secondary system which monitors that process, the one doing the accident analysis and the following recommendations. In any system which has an accident or incident investigation system, such a secondary system is in place. The problem is that ones the recommendations from the accident investigations has changed a system to be stable in the face of a new kind of disturbance, processes can start to return the system to its *previous state of stability*. That is, many organizations show resistance to positive events - processes that would increase their resistance to negative events.

In some cases, the organization gradually becomes unable to imagine a similar event, even after a finished investigation where recommendations have been made. They achieve a heightened state of sensitivity to negative events, just after the event. But that sensitivity then degrades over time. Thus, the sensitivity does not result in improved resilience in the organization, instead it is just a temporary effect that disappears not long after it is introduced. In other cases, a resilience-improving process might be proposed but not implemented, or implemented but later dismantled. This problem was also emphasized by Westrum (2006, p. 22) “The focus is on assessing the organization’s adaptive capacity relative to challenges to the capacity – what sustains or erodes the organizations adaptive capacities?”. To maintain resilience, consequently, there might be a need for a third, permanent, system/process that monitors that the suggested recommendations for improving resilience and stability are followed.

Looking at this further, we get a situation similar to a Russian Matryoshka doll, outside each process, there is another process containing it, and monitoring and maintaining it… but is there a larger doll outside that doll? (see Figure 2.) Normal activity in a non-resilient system might on the surface look like activity in a resilient system… so if the capability of resilience has vanished, how do you get it back, especially if you do not know that it is gone?

Fig. 2. Resilience maintenance as Russian Matryoshka dolls. Outside each resilience-maintaining process, there can be another process containing it, and monitoring and maintaining it… but is there a larger doll outside that doll, maintaining it?

3 CONCLUSION – IMPLICATIONS FOR ACCIDENT INVESTIGATIONS

We conclude that basing safety work on ‘requisite imagination’, at least for unexampled events, might well be a mirage. What we mean by that is that it is hard or even impossible to create a system which maintains stability in the face of irregular or unexampled events. Instead, we propose that efforts are aimed at ‘requisite interpretation’, the ability to see the facts of an accident or disaster and actually accept that it happened and respond properly. To ‘respond properly’ does not necessarily mean small adjustments, but rather to have a preparedness to make drastic re-configurations and accept that we cannot foresee all types of events.

Recommendations for action should therefore focus not only on the primary system, the target of an accident investigation, but also on the secondary system, that performs the investigation. Any ‘safe’ system faces the Matryoshka problem, that its resilience-stability balancing process (such as accident investigation, production and implementation of recommendations from such investigations) in itself may neither be resilient, nor stable.

In conclusion, we find that accident investigations should produce recommendations aimed at balancing stability and resilience, rather than trying to maximize one, or both, of them.

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