Measuring and visualizing resilience: a railway example

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Abstract. Two studies are presented where a method for measuring and visualizing resilience engineering in a railway domain is developed. In Study 1 a new questionnaire measuring resilience abilities of an organizational function were tested for descriptive purposes. In Study 2, the questionnaire was used proactively where the aim was to predict resilience abilities after an organizational change. The result from the two studies shows that resilience abilities may be measured and visualized effectively both for descriptive and predictive purposes. Implications for the HTO-perspective and future development are discussed.

Keywords: Resilience, method development, risk analysis, organizational change

1. Introduction

Production processes in many services, industries and modes of transportation involve risks. These risks must be managed on a systemic level, meaning that safety is created in the interaction between human, technical and organizational (HTO) systems necessary for the adequate performance of the overall sociotechnical system (IAEA, 2013, Rasmussen, 1997). The concept of Resilience Engineering takes a systemic view on safety, and may be seen as the ability of an organization to maintain normal operations and regain a dynamically stable state when responding to abnormal situations. According to the Resilience Engineering concept organizations should not only look at what goes wrong when creating safety but also look at what goes right (Hollnagel, Woods & Leveson, 2006). Four main abilities that an organization should have in place to be considered resilient are: 1) *Responding*. The ability to respond to abnormal situations. 2) *Monitoring*. The ability to monitor normal operations. 3) *Learning*. The ability to learn from past experiences, 4) *Anticipating*. The ability to anticipate future situations (Hollnagel, Pariés, Woods & Wreathall, 2011). There are methods for applying Resilience Engineering principles available (Hollnagel, 2012; Hollnagel et al., 2011). However, the concept of Resilience Engineering is not easily measured and implemented in practice (Sheridan, 2008).

1.1 Present study

A railway system is an example of a complex system where Resilience Engineering principles may be appropriate (Collins, Schmid & Tobias, 2013; Wilson, 2009). The overall aim of the present study was to develop the RAG method (Hollnagel et al., 2011) further by measuring and visualizing organizational resilience on a functional level in a railway system. The purpose of the present paper is to show how the RAG method may be used in an applied setting. Two studies were performed within the same infrastructure manager organization but in different locations and contexts, for practical reasons.

2. Study 1

The aim of Study 1 was to measure resilience abilities descriptively in an infrastructure manager organization. A Task Analyses (Anette, Stanton & Anette, 2000) was performed to analyse possible risks in connection with reducing the number of train traffic controllers in the organization. In connection with the Task Analyses participants were asked to rate how their organization handles normal and abnormal situations in general.

2.1 Method

Participants. A total of 6 employees from an infrastructure manager participated. Study 1 took place as a part of a Task Analysis (TA), and the participants were selected based on relevant knowledge about the task analysed.

Procedure. The participants were asked to complete a questionnaire concerning their organization´s ability to handle abnormal and normal situations. The questionnaire was distributed after the TA was completed.

Measures. The questionnaire was meant to tap the four resilience abilities; learning, responding, monitoring and anticipating. The questionnaire was in Swedish and all examples below are translated to English. For each of the four resilience abilities, 5 statements were constructed (see Table 1). The participants were asked to rate how their department/function complies with the statements. The statements were rated on an eleven-step scale ranging from 0, *very low degree* to 10, *very high degree.*

Statistical analyses. Means were calculated for each of the four resilience abilities. In addition, the mean score for each statement were calculated and presented in Table 1.

2.2 Result

The means for each of the four resilience abilities were calculated. The result is presented in Figure 1 where it can be seen that the participants rate their organization to be better at learning and monitoring compared to responding and anticipating. The ratings for monitoring and learning are in the middle of the scale.

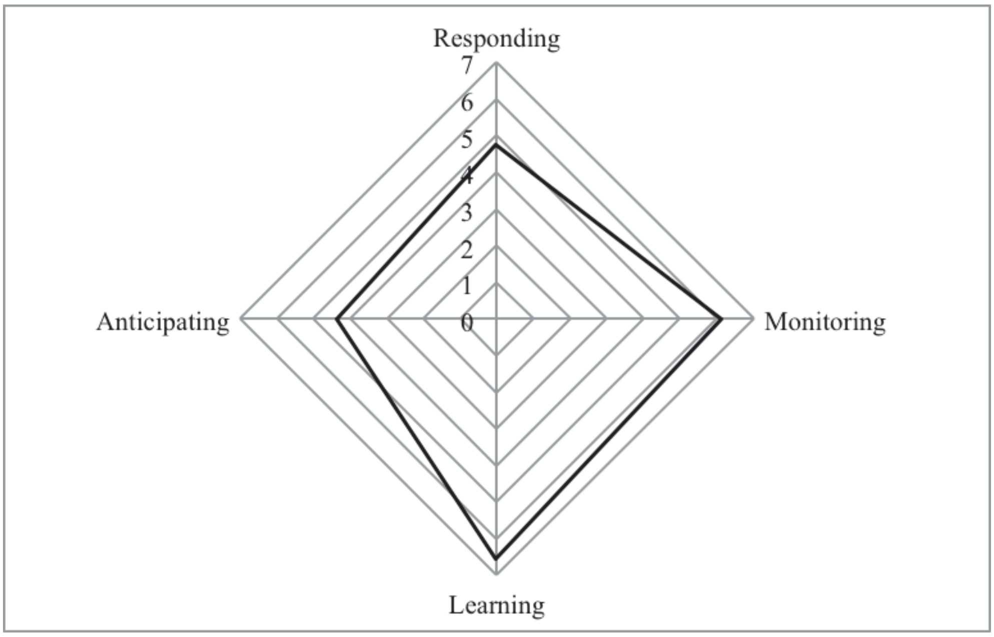

Figure 1. Means for each of the four resilience abilities. Scale range: from 0 = very low degree to 10 = very high degree, n=6.

Table 1. Mean ratings for the individual statements from both Study 1 and Study 2. Scale

range: from 0 = very low degree to 10 = very high degree.

	Infrastructure manager, Study 1 (*n* = 6)	Infrastructure manager, Study 2 (*n* = 2)	Infrastructure maintenance, Study 2 (*n* = 1)	Train operator, Study 2 (*n* = 2)
Responding				
1. My organization is good at handling abnormal situations	7.7	3.5	4.0	7.0
2. Abnormal situations are regularly practiced.	2.3	0	2.0	3.0
3. There is a list of events for which the organization has prepared responses.	2.5	2.5	4.0	8.0
4. The organization has adequate resources (people, materials, competence, expertise, and time) to handle abnormal situations.	5.7	1.5	5.0	7.5
5. It is clearly described when to return to normal operations after an occurrence.	5.7	9.0	6.0	7.0
Monitoring				
6. My organization continuously monitors normal functioning of the system.	7.2	2.0	6.0	5.5
7. My organization continuously monitors occurrences.	7.2	3.0	6.0	6.5
8. My organization continuously monitors potential risks.	6.7	3.0	3.0	7.5
9. The results from the continuous monitoring are communicated to the personnel.	4.7	2.0	3.0	5.5
10. The organization has adequate resources (people, materials, competence, expertise, and time) to perform monitoring.	5.0	1.5	5.0	6.0
Learning				
11. My organization learns from occurrences.	7.8	5.5	5.0	9.0
12. My organization learns from what is functioning well.	7.0	8.5	5.0	7.5
13. My organization is good at taking actions to make sure that everything works as planned.	7.0	6.5	3.0	7.5
14. My organization is good at following up the effects of actions taken.	5.5	6.0	3.0	5.0
15. Information about actions taken is communicated to the personnel.	5.3	5.5	3.0	6.5
Anticipating				
16. My organization works actively to try to anticipate future risks.	5.5	4.5	2.0	7.0
17. My organization works actively to try to anticipate future possibilities.	5.5	3.5	5.0	5.5
18. My organization is trying to make long term anticipations.	4.7	5.0	4.0	4.0
19. My organization is good at communicating future risks to the personnel.	2.8	5.0	3.0	4.5
20. My organization is good at communicating future possibilities to the personnel.	3.3	6.5	5.0	4.5

3. Study 2

The aim of Study 1 was to measure resilience abilities descriptively in the organization. Study 2 extends Study 1 by applying the questionnaire proactively to predict resilience abilities after an organizational change. In addition, 3 interacting organizations participated. Study 2 was performed in connection with a Task Analysis and was performed in a different unit, location and context but within the same organization as in Study 1. In addition, two interacting organisations affected by the organisational change participated. The organizational change concerned dispatching of trains across a national border where two different languages are used. Before the organizational change train dispatching was handled by a local train traffic controller with knowledge of both languages spoken. After reorganization train dispatching was planned to be handled by a remote train traffic controller without knowledge of the language spoken by the train traffic controller across the border. A solution with an interpreter as a middle hand between train traffic controllers was planned to handle the new situation. This new situation was risk analysed using a Task Analyses. In connection with this participants were asked to rate how they believe that their organization would handle both normal and abnormal situations when an interpreter is acting as a middle hand between train traffic controller.

3.1 Method

Participants. A total of 5 employees participated (2 from an infrastructure manager, 1 from an infrastructure maintenance organization, 2 from a train operator). Study 2 took place as a part of a Task Analysis, TA. The participants were selected based on relevant knowledge about the task analysed.

Procedure. The participants were asked to complete a questionnaire concerning their organization´s ability to handle abnormal and normal situations. The questionnaire was distributed after the TA was completed.

Measures. The statements (see Table 1) were the same as in Study 1 and meant to tap the four resilience abilities; learning, responding, monitoring and anticipating.

Statistical analyses. Means were calculated for each of the four resilience abilities. In addition, the mean score for each statement were calculated and presented in Table 1.

3.2 Result

The means for each of the four resilience abilities were calculated for each of the interacting organizations. The result is presented in Figure 2 where it can be seen that the participants from the infrastructure manager rate their organization to be better at learning and anticipating compared to responding and monitoring. The ratings from the infrastructure maintenance company and the train operator are more evenly distributed across the four abilities and higher on responding and monitoring compared to the railway authority. However, most of the ratings are on the middle to lower part of the scale.

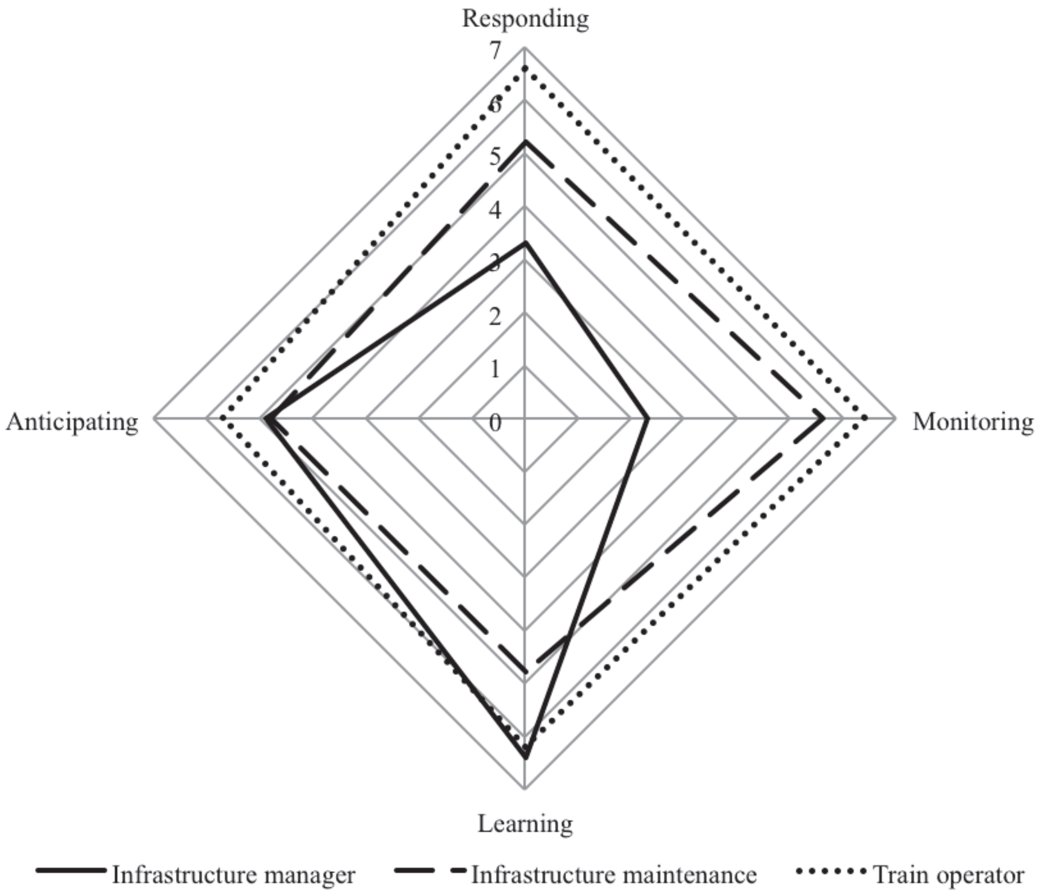

Figure 2. Means for each of the four resilience abilities from each of the interacting organisations, infrastructure manager (n=2), infrastructure maintenance (n=1), and train operator (n=2). Scale range: from 0 = very low degree to 10 = very high degree.

4. General Discussion and Conclusion

Risk analyses traditionally focus on what may go wrong (Hollnagel et al., 2011). In contrast, Resilience Engineering highlights the importance of also looking on things that goes right, which are everyday operations. By doing so there will no longer be any conflict between safety and economy, since focusing on what goes wright and improving this will increase efficiency, and thereby economy. The ability of an organization to be resilient is important when creating safety as well as efficiency. Therefore it is valuable to measure organization´s resilience abilities to identify areas where improvements can be made. However, although Resilience Engineering may rest on a sound theoretical base, it is not easily measured and applied in practice (Sheridan, 2008).

The result from the two studies show that the resilience abilities may be measured and visualized when applied in practice. Formulation of questions and optimal pattern distribution of abilities must be determined from case to case depending on factors such as type of organization, function, and operational environment (Hollnagel et al., 2011). However, it is argued here that it is reasonable for an infrastructure manager to have an even pattern distribution across the four resilience abilities. The result from Study 1 showed that it may be advantageous for the infrastructure manager to be better at responding and anticipating. The result from Study 2 showed that the infrastructure manager could be better at responding and monitoring. Furthermore, the overall result from the two studies indicate that all the involved organizations may be benefitted from a general improvement in resilience abilities, since most ratings were distributed in the middle of the scale.

The present study is a step towards a fully developed method for measuring resilience in organizations. However, more research and development needs to be done. The set of questions asked in the present study about the four resilience abilities were limited. In addition, the number of participants was too low to allow formal statistical analyses of the psychometric properties of the scale and to make valid conclusions. Future research should focus on developing more questions with more participants. The limited number of participants has meant that priority has not been given to presenting the full range of statistics that is normally required. However, the main contribution of the present paper is to show how the RAG method can be applied in practise, which historically has been problematic (Sheridan, 2008).

Resilience Engineering takes a systemic view point by focusing on functions of the system rather than only individual parts. The questionnaire used in the present study focused on the organization and its functions, and how these interact to create a resilient system able of handling normal as well as abnormal situations. Looking at what goes wright requires that a HTO-perspective is taken. Instead of looking for human error and blame individuals organizations should try to understand why people behave as they do in any given situation with the information they have at hand at every given moment. Normally accidents happen when people do what they normally do, that is everyday work (Hollnagel et al., 2006). Therefore focus should be on how individuals interact with technology and organizations in everyday situations and how they make sense of their situation and work efficiently with the organizational means provided. Taking a resilience viewpoint may mean a step away from human error towards human sense making.

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