CAN TEAM REFLECTION OF RAIL OPERATORS MAKE RESILIENCE-RELATED KNOWLEDGE EXPLICIT? - AN OBSERVATIONAL STUDY DESIGN

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Abstract

The essential resilience capabilities – monitoring, responding, learning and anticipating - have all in common the need for relevant signals and the ability to transform them into action. However, this transformation is often lacking as seen from accident analyses revealing disturbances that are either not noted or ignored in the process leading up to the undesired result. This paper proposes to focus on signals occurring because of movements from and to system boundaries and use them for team reflection. The reflection is expected to make implicit knowledge explicit, being a first step of the needed transformation to action. An observational study is designed at a rail control post where rail signal operators reflect at the end of their shift. They reflect on the punctuality boundary through an on-line application, called the Resiliencer-punctuality. The application presents delay-development of trains, during a shift, with respect to a previous chosen period. Furthermore it provides search instruments to find specific trains of interest stimulating the reflection. A verbal analysis method is used to analyze the reflection discussion and to show a relation to resilience through learning and anticipating intentions. In addition we seek for repetitive elements in different cases to prove the learning potential. The observation designed should support the hypothesis that team reflection, on movements towards boundaries, increases resilience of the rail socio-technical system.

1 INTRODUCTION

Resilience engineering researches, among other aspects, the ability of a socio-technical system to reorganize and adapt to the unexpected and unforeseen (Hollnagel, Woods, & Leveson, 2006). Hollnagel (2009) theorizes that a sociotechnical resilience system needs four essential capabilities: responding, monitoring, learning and anticipating. These capabilities differ in moment and scope – actual, critical, factual and potential – but have in common the need for 1) relevant signals and 2) the ability to transform them into action. This transformation is often lacking as seen from accident analyses revealing disturbances that are either not noted or ignored, leading up to the undesired outcome (Hall, 2003; Stanton & Walker, 2011). The sharp end can play an important role in this transformation. Cowley & Borys (2014) describe an organizational elasticity model with competent and knowledgeable workers at the sharp end to respond to drifts of performed work (Dekker, 2011; Hollnagel, 2008; Weick & Sutcliffe, 2007). Bracco, Piccinno, & Dorigatti (2014) go further by presenting nine steps to progress from the individual at the sharp end to the organization at the blunt end. However, it is not clear from the studies described above where the signals are identified and how they are transformed into explicit knowledge the organization can act upon. Signals appear throughout normal processes, having a large variability and are not necessarily related to the resilience of the system causing a large efficiency-thoroughness-trade-off (Hollnagel, 2009a). In an earlier study (Siegel & Schraagen, 2014b), we proposed to focus on signals related to the system boundaries to reveal resilience changes. Focusing on these resilience-related signals reduces the signal trade-off effort but still needs a process to turn them into resilient behavior - learning and anticipating. In this paper, we suggest to use team reflection to increase the amount of explicit knowledge, relevant to system resilience, enabling learning and anticipation. Team reflection (Ellis, Carette, Anseel, & Lievens, 2014; Reymen, 2003; Schippers, Den Hartog, & Koopman, 2007; Schippers, Edmondson, & West, 2014; West, 2000; Wiedow & Konradt, 2010), includes behaviors such as questioning, analysis, making use of knowledge explicitly, reviewing past events with self-awareness, and coming to terms over time with a new awareness (West, 2000). Team reflection, in a loop with planning and action, is used in a broader reflexive process (West, 2000) where team members collectively reflect upon the team's objectives, strategies, and processes. However, the team reflection proposed here goes beyond the team's span of control, which is located at the sharp end, knowing details not seen by the rest of the organization. The question arises whether team reflection exposes knowledge beyond the responsibility of the team and whether it adds to the existing explicit knowledge. Thus, the main aim of this paper is to develop theory and method, and design an observational study in a rail system environment to verify the effectiveness of the proposed method. In the next section, we describe the theory and method for use in the operational environment. Next, we describe the rail environment of the study including proposed processes. We end with a discussion on the expected results.

2 METHOD

We describe at first the setting to understand the context of the methods. A Dutch rail-post responsible for the area North and West of Amsterdam with about fifty rail stations and thousand daily train trajectories. The work, performed 24/7, assigned to rail signalers during the day across four workstations. The rail signalers have to monitor the system planning and execution. During disruptions, they adjust the planning, manually direct the system and follow safety procedures and protocols including communication with train drivers and other personnel. They enter information about every train delay of more than three minutes through a dedicated application on the cause of the delay. This is the only place where they capture their knowledge about the system. The rail signalers perform their tasks and go home after their shift without any organized discussion about their work. Due to large disruptions they may be approached for questioning. The team reflection method of the rail signalers at the end of their shift is a new activity described in the next subsection. The following subsection describes the method used in the reflection-tooling and the last subsection describes the analysis method used to classify verbal expressions during the reflection.

2.1 Team reflection of rail signal operators at the end of their shift

The team mentioned in this paper, is a group of rail signal operators working together during a shift at a rail control post. Team reflection has mainly been investigated with respect to the performance of the team itself. West (2000) defines the team reflection subject as the group's objectives, strategies (e.g., decision making) and processes (e.g., communication). The results of such a reflection can be fed back into the planning and action/adaptation loop to improve team performance such as their information processing (Schippers et al., 2014). However, in our case the objective of reflection is to transform implicit to explicit knowledge, at the sharp end, relevant to the resilience state of a socio-technical system. This knowledge goes beyond the direct responsibility of the team. Implicit knowledge is tacit knowledge, a form of private knowledge that is treated as "informal," and even, in a sense, "unconscious" knowledge (Day, 2005; Polanyi, 1969), that can be transformed to explicit knowledge (Frappaolo, 2008). We are interested in the implicit knowledge, relevant to system resilience, acquired throughout the regular work of the signalers. Resilience is about the behavior of the socio-technical system (STS) when it approaches and passes its boundaries (Siegel & Schraagen, 2014a; Woods, 2006). We assume that resilience related knowledge is released when the subject of team reflection is the movements towards and from those boundaries. We depict the proposed in figure 1. The signal operators interact individually with the rail STS, where they are part of as well. Throughout the interaction they gain individual implicit knowledge on the rail STS, which is partially made explicit through data entry by the signalers themselves into the system. Through the reflection they exchange some of their implicit knowledge, causing it to become explicit.

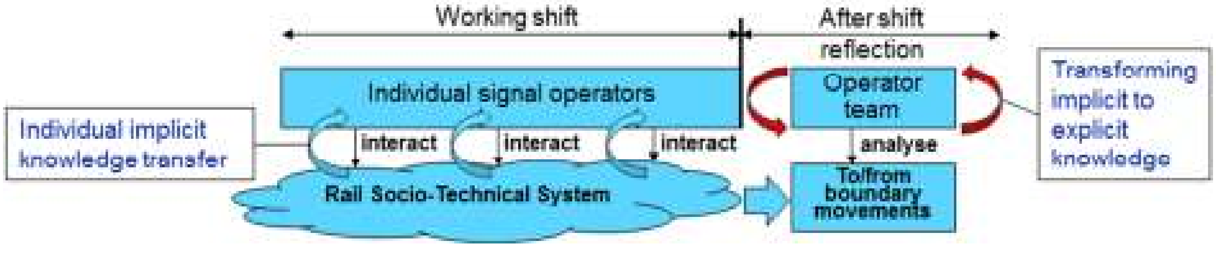

Figure 1 *After shift reflection*

2.2 Movements towards and from the performance (punctuality) boundary

In order to motivate the team reflection on topics related to resilience, we suggest to reflect on movements of the Operating System (OS) towards and from the boundaries as described previously (Siegel & Schraagen, 2014a, 2014b). In this paper, we focus only on the performance boundary and particularly punctuality. Performance in the rail sector is a combination of punctuality and capacity. In the short term only punctuality plays a role since capacity is nearly constant through its year planning. Punctuality of rail operations is well defined as the difference between planned (i.e. according to the latest published timetable) and actual moments of arrival or departure from a specific station (Goverde, 2005; Hansen, 2010). However in our case, we deal with many stations in a large area, many trains, different routes and shift periods, which need an extended punctuality definition to distinguish well between all these ingredients. This definition is the basis for the presentation and analysis during reflection. The context is a control area A and m stations S_j , j=1, ..., m. In this area are n_A trains, T_i i=1,..., n_A, driving during de shift period between t_{shift}^{start} and t_{shift}^{end}. Train T_i has at station S_j a punctuality of $P_{i,j} = t_{i,j}^{act,dep/arr} - t_{i,j}^{plan,dep/arr}$ being positive when the train is delayed. Where $t_{i,j}^{act,dep/arr}$ is the *actual* moment of arrival (arr) or departure (dep) of train T_i at station S_j and $t_{i,j}^{plan,dep/arr}$ is the *planned* moment. The train T_i has a route starting at station S_{Bj} and ending at station S_{Ej} where $S_{Bj}, S_{Ej} \in \{S_j, j = 1, \dots, m\} \in A$. The punctuality of train T_i at the start of its route in area A (station S_{Bj}) is: $P_{i,Bj} = t_{i,Bj}^{act,dep} - t_{i,Bj}^{plan,dep}$ and at the end of his route (station S_{Ej}) $P_{i,Ej} = t_{i,Ej}^{act,arr} - t_{i,Ej}^{plan,arr}$. A train, in this context, is defined as delayed when $(P_{i,Bj}\ or\ P_{i,Ej}) \geq t_d$, where t_d is a time duration set by de rail sector. In our case t_d = 3 min. This definition causes delays of train T_i *within* its trajectory at area A not be accounted as a delay.

Team reflection needs an indication on the performance of the trains within area A. We have chosen to calculate the punctuality increase of delayed trains during the shift. We present its relation to the same parameter during a reference period, which is the last week, month or year.

The increased punctuality of train T_i in area A is $\Delta_A P_i = P_{i,Ej} - P_{i,Bj}$. The average increased punctuality of delayed trains T_i in area A during shift period between t_{shift}^{start} and t_{shift}^{end} is $\overline{\Delta_A P_{shift}} = \frac{1}{n}\sum_{i=1}^{n} \Delta_A P_{i,shift}$ where n is the number of delayed trains driving in area A within the shift interval $t_{shift}^{start} \leq t_{i,Bj}^{act,dep}\ or\ t_{i,Ej}^{act,arr} \leq t_{shift}^{end}$ causing trains, crossing the shift boundary, counted in both shifts. The average increased-punctuality of delayed trains in area A during a reference period of shifts is $\overline{\Delta_A P_{ref}}$.

Movements towards the punctuality boundary are identified through the relation between $\overline{\Delta_A P_{shift}}$ and $\overline{\Delta_A P_{ref}}$. When the first is larger than we talk about, a movement occurs towards the boundary, otherwise the movement is away from the boundary.

We have transformed the above into an application called the Resiliencer-punctuality (fig.2). The application has two main modes: Live and Analysis. Live mode presents in real-time the comparison between $\overline{\Delta_A P_{shift}}$ and $\overline{\Delta_A P_{ref}}$. Analysis mode freezes the live data and allows searches for particular trains and punctuality increase. The results are split in passenger and freight trains, since both have a different characteristic concerning time delays. Passenger trains are tightly coupled to the on-line published time-table, while freight deviates much easier and has a lower punctuality priority. We have split the controlled area into four main trajectories. This helps to understand the results of the whole area. On the right hand side of the live mode display are the four trajectories. In the analysis mode we integrate search functions to focus on a particular train of interest. We present a graph of its trajectory with its delays (see lower right window in the analysis mode display).

Figure 2 *The Resiliencer-punctuality in live mode (left) and analysis mode (right)*

2.3 Verbal analysis

To analyze implicit to explicit knowledge transformation during team reflection, we use the verbal analysis method. This method quantifies subjective or qualitative coding of verbal utterance contents (Chi, 1997). In contrast with the verbal protocol analysis (Ericsson & Simon, 1993), which focuses on capturing the process of problem solving to gain knowledge, the verbal analysis focuses on capturing the representation the solver has. In our case, there is no direct problem solving, but knowledge is presented by the participants throughout the reflection, which is shared by the team and needs a methodology to be captured. To uncover what a participant knows and shares with a colleague needs analysis of the verbal utterances. We propose the following steps to achieve a set of propositions, along with a procedure to organize the verbal content.

1. Reducing the protocols

   The rail operations are organised around train numbers, which are uniquely defined during a day by its route and order of appearance on the route. These train numbers, which are central in the Resiliencer-punctuality as well, are taken as the definition of discussion cases. In all discussions, we assume an initial or leading train number, which we will use to split the discussion in cases and rank them in order of discussion length. The analysis will be concentrated on the longest discussion cases, assuming most knowledge transfer, thus most interesting for this research.

2. Segmenting the cases into semantic features, such as ideas, argument chains, or topics of discussion.

   This approach of semantics was also used by Chi (1997) and preferred over the non-content segmentation unit of a sentence, or a part of it. Because of two reasons: 1) an idea might need several sentences to convey and 2) the same idea might be repeated several times and should be recognized and treated as such. This content segmentation has a subjective bias and should therefore be segmented and compared to a second researcher as done for the coding of these segmentations.

3. Coding of the segments

   The segments are coded by at least two coders and compared to each other. The following coding scheme will be used:

   - Type of segment content: 1) Fact ; 2) Reasoning {+ Depth of reasoning}; 3) Suggestion ; 4) Opinion; 5) None of the above
   - Coding used in the Dutch reporting system for allocating delays (relevant for comparison):
     - Transporter (train operator): 1) Rolling stock; 2) Personnel; 3) commercial process; 4) Train knock-on delays
     - Infrastructure operator: 1) Civil engineering; 2) Defect Infrastructure; 3) Traffic management
     - Third parties: 1) Weather; 2) (near) Collision; 3) Strike
   - Knowledge within span of team-control: Yes/No

The analysis based upon the above coding will result in: 1) relation diagram of knowledge segments and 2) percentage of knowledge beyond the span of team control. The relation of knowledge segments will show the depth of reasoning, which is a type of learning (Felder & Henriques, 1995). The suggestions are a first step of anticipation. Learning and anticipation are both resilience cornerstones (Hollnagel, 2009b).

3 OBSERVATIONAL STUDY DESIGN

The study design at the Dutch rail-post described above, is about the introduction of team reflection (figure 3 in the top-center). At the end of the rail signal operators' duty (figure 3 in the center) they will discuss de- and increased delays within their controlled area. The will use for that the Resiliencer-punctuality (figure 3 left side). The application has been configured for the specific rail-post. It presents in live mode the punctuality status and provides in analysis mode the ability to search for logistic details (i.e. the delay progress of a specific train). The post-area has been split up into four main trajectories covering all stations and each trajectory is controlled by two workstations. This causes at least two rail signalers to relate to the results of a main trajectory. The results of the four trajectories are combined into results of the whole post during a shift.

The four rail signalers on duty will stop their work an hour earlier, during the observational study period, for a reflection session together with their team leader. They will ask themselves the following generic questions:

- Did our shift today proceed better than the average of last period? Why?

- What were the circumstances for the difference?
- Which of the identified circumstances could occur again in the future?
    - What can we learn from that?
    - How can we deal with these circumstances and what can we do differently?

For answering these questions, they can use the Resiliencer-punctuality and analyze the numerical punctuality progress in their area. However, reasoning beyond the numerical data can only be done with help of their personal knowledge and notes made during their shift (figure 3 in the center). We record the discussion and analyze it (figure 3 top right side) as described in the previous section. This will result in an explicit knowledge flow, reasoning, learning and action intentions (figure 3 bottom right side). We will compare these results with the explicit knowledge entered in the reporting system and verified through interviews (figure 3 bottom).

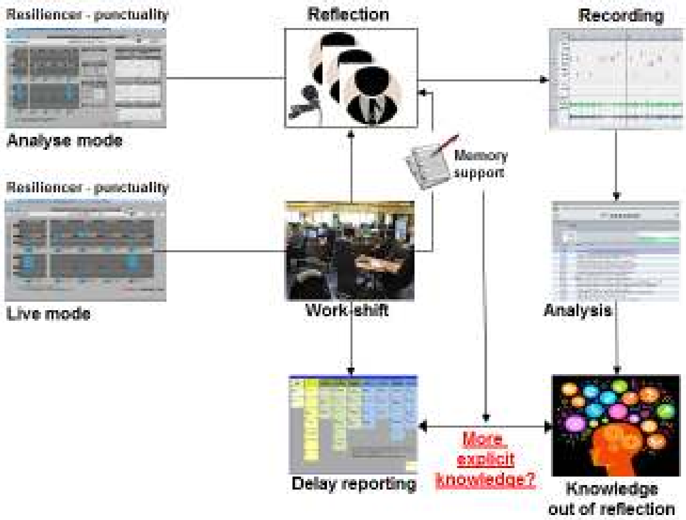

***Figure 3** Illustration of study design*

4 DISCUSSION

The main challenge of the team reflection analysis is to show that explicit knowledge expressed during the reflection relates to resilience. Resilience is defined, among others, as the behavior of the STS near and beyond its boundaries (Woods, 2006). This leads to the assumption that knowledge arisen through discussion on movements towards and from these boundaries, relates to resilience by definition. However, this theoretical reasoning still needs confirmation. The first approach identifies cases where the system gets out of balance, which is a state related to resilience. In these cases we search for issues, which team reflection identified earlier in a previous case. A successful match proves the effectiveness of team reflection, however it needs coincidence. To enlarge our success rate in finding resilience-related knowledge, we use two more approaches. The first of these is comparing knowledge in the reporting system with explicit knowledge as result of team reflection. We assume that more and deeper reasoning of the latter improves the resilience of the system, since it can be of use when adaptation is needed. The second added approach is based upon Hollnagel's (2009b) cornerstones of learning and anticipation. We will seek for reasoning and induction with the new knowledge, being a component of learning (Felder & Henriques, 1995). Suggestions and opinions approve the intent for anticipation. The combination of these approaches should support the hypothesis that team reflection, on movements towards boundaries, increases resilience of the rail socio-technical system.

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REFERENCES

Bracco, F., Piccinno, T. F., & Dorigatti, G. (2014). Turning variability into emergent safety: The resilience matrix for providing strong responses to weak signals. In *5th Resilience Engineering Symposium* (pp. 23–27). Retrieved from http://hdl.handle.net/1811/60454

Chi, M. T. H. (1997). Quantifying qualitative analyses of verbal data: A practical guide. *Journal of the Learning Sciences*, *6*(3), 271–315. doi:10.1207/s15327809jls0603_1

Cowley, S., & Borys, D. (2014). Stretching but not too far : Understanding adaptive behaviour using a model of organisational elasticity. *Journal of Health and Safety, Research and Practice*, *6*(2), 18–22.

Day, R. E. (2005). Clearing up "implicit knowledge": Implications for knowledge management, information science, psychology, and social epistemology. *Journal of the American Society for Information Science and Technology*, *56*(February), 630–635. doi:10.1002/asi.20153

Dekker, S. (2011). *Drift into failure - from hunting broken components to understanding complex systems*. Farnham, Surrey: Ashgate Publishing Limited.

Ellis, S., Carette, B., Anseel, F., & Lievens, F. (2014). Systematic reflection: Implications for learning from failures and successes. *Current Directions in Psychological Science*, *23*(1), 67–72. doi:10.1177/0963721413504106

Ericsson, K. A., & Simon, H. A. (1993). *Protocol analysis: Verbal reports as data* (revised ed.). Cambridge, Massachusetts: MIT Press.

Felder, R. M., & Henriques, E. R. (1995). Learning and Teaching Styles. *Foreign Language Annals*, *28*(1), 21–31.

Frappaolo, C. (2008). Implicit knowledge. *Knowledge Management Research & Practice*, *6*(October 2007), 23–25. doi:10.1057/palgrave.kmrp.8500168

Goverde, R. M. P. (2005). *Punctuality of railway operations and timetable stability analysis. PhD thesis*. Delft University of Technology. Retrieved from http://repository.tudelft.nl/view/ir/uuid:a40ae4f1-1732-4bf3-bbf5-fdb8dfd635e7/

Hall, J. L. (2003). Columbia and Challenger: organizational failure at NASA. *Space Policy*, *19*(4), 239–247. doi:10.1016/j.spacepol.2003.08.013

Hansen, I. A. (Ed.). (2010). *Timetable Planning and Information Quality*. WIT Press.

Hollnagel, E. (2008). Safety management - looking back or looking forward. In E. Hollnagel, C. P. Nemeth, & S. Dekker (Eds.), *Resilience Engineering Perspectives, Volume 1: Remaining Sensitive to the Possibility of Failure* (pp. 63–77). Hampshire: Ashgate Publishing Limited.

Hollnagel, E. (2009a). *The ETTO principle: efficiency-thoroughness trade-off: why things that go right sometimes go wrong*. Farnham, Surrey: Ashgate Publishing, Ltd.

Hollnagel, E. (2009b). The four cornerstones of resilience engineering. In C. P. Nemeth, E. Hollnagel, & S. Dekker (Eds.), *Resilience Engineering Perspectives. Volume 2: Preparation and restoration* (pp. 117–134). Farnham, Surrey: Ashgate Publishing Limited.

Polanyi, M. (1969). Knowing and being: In M. Grene (Ed.), *Essays by Michael Polanyi* (p. 264). Chicago: University of Chicago Press.

Reymen, I. M. M. J. (2003). Research on design reflection: overview and directions. In *DS 31: Proceedings of ICED 03, the 14th International Conference on Engineering Design, Stockholm* (pp. 1–10).

Schippers, M. C., Den Hartog, D. N., & Koopman, P. L. (2007). Reflexivity in teams: A measure and correlates. *Applied Psychology*, *56*(2), 189–211. doi:10.1111/j.1464-0597.2006.00250.x

Schippers, M. C., Edmondson, A. C., & West, M. A. (2014). Team reflexivity as an antidote to team information-processing failures. *Small Group Research*, *45*(6), 731–769. doi:10.1177/1046496414553473

Siegel, A. W., & Schraagen, J. M. C. (2014a). A method to reveal workload weak-resilience-signals at a rail control post. In D. Harris (Ed.), *HCII 2014* (pp. 82–93). Springer Berlin Heidelberg. doi:10.1007/978-3-319-07515-0

Siegel, A. W., & Schraagen, J. M. C. (2014b). Measuring workload weak resilience signals at a rail control post. *IIE Transactions on Occupational Ergonomics and Human Factors*, *2*(3-4), 179–193. doi:10.1080/21577323.2014.958632

Stanton, N. A., & Walker, G. H. (2011). Exploring the psychological factors involved in the Ladbroke Grove rail accident. *Accident; Analysis and Prevention*, *43*(3), 1117–27. doi:10.1016/j.aap.2010.12.020

Weick, K. E., & Sutcliffe, K. M. (2007). *Managing the unexpected: Resilient performance in an age of uncertainty, 2nd edition*. San Francisco, CA: John Wiley & Sons, Inc.

West, M. (2000). Reflexivity, revolution and innovation in work teams. In M. M. Beyerlein, D. A. Johnson, & S. T. Beyerlein (Eds.), *Product development teams* (Vol. 5, pp. 1–29). Stanford, CT: JAI Press.

Wiedow, A., & Konradt, U. (2010). Two-dimensional structure of team process improvement: Team reflection and team adaptation. *Small Group Research*, *42*(1), 32–54. doi:10.1177/1046496410377358

Woods, D. D. (2006). Resilience engineering: Redefining the culture of safety and risk management. *Human Factors and Ergonomics Society Bulletin*, *49*(12), 1–8.