Using Event Data in German Railways for a Systemic Perspective of System Design and Optimization

O. Sträter & M. Arenius

Department of Work and Organisational Psychology,
University of Kassel, Kassel, Germany

INTRODUCTION

The highly automated railway industry is considered to maintain a high safety standard. However events and (though rare) accidents show spots for safety improvements. I a high reliability organization like rail the key question to answer after the occurrence of an event is to decide whether the observed causes are of sporadic or systematic nature. A second issue is that - while the technical components are more and more reliable - the causes often lie in a human contribution to these events. More recent research has indicated, that - in order to understand events where the human plays a critical role to identifying critical interactions between components contributing to accident causation on a system level. Additionally (and closely related to this issue), a need for better explanatory models for human performance variability is required (e.g. Hollnagel, 2006).

This article will present an approach to analyze events regarding human contributions to safety and will provide results from an investigation of 142 railway events from Germany from 2000 to 2010. The study evaluates the relation of causes for human performance deviations and provides an explanatory model for human performance. Based on this and the assessment of the causal relationships in the events, an approach for optimization of the system regarding safety is developed. The analysis of the accidents was conducted with the 2nd generation HRA method CAHR (Sträter, 1997, 2005) that has been extended by positive aspects observable in events to include herewith the key concept of resilience engineering (Arenius et al., 2011). The results demonstrate the benefits of employing event analysis and Human Reliability Assessment (HRA) for system design and optimization.

1 1 EVENT ANALYSIS AND HUMAN PERFROMANCE ASSESSMENT

1.1 *1.1 General aspects*

The appropriate consideration of Human factors is essential for safety in any complex technical system. Sources of the human impact on safety can be manifold. Usually human reliability issues are allocated at the ‘sharp end’ of the system. In railway this is the operational level of train-driver and dispatcher. However, there could also be other human influences on the reliability of the system; these are for instance maintenance issues, managerial or organizational aspects, and also inter-organizational and regulatory issues that can play a role for safe operation (cf. Perrow, 1999; Leveson, 2004).

There are different approaches to consider the human aspects in safety. One is the design of technical barriers to prevent human error to have a safety impact. However this strategy causes additional complexity that in turn will increase the safety-criticality of the human contributions (cf. also Hollnagel, 2006). Others relate to re-qualifications, training or redesign of functions.

If one needs to decide the best means to improve safety, appropriate data about the human reliability issues need to be present. Often the appropriateness of a mitigation means is determined by the technical or the economic feasibility but not by the most effective approach due to lacking or incomplete human reliability data. The lack in a human related design of mitigations is accelerated by the fact that the 'Human Issue' is often seen as the weak and ambiguous element of system design that needs to be eliminated by a better to be determined system element (i.e., an automat). However, history in other highly automated systems like nuclear power plants showed that automation is rather increasing than decreasing the importance of the Human for safe operations.

Looking across different technical domains and Human properties for safety, show that the Human issues on safety are as determined as for technical aspects of the system and that clear and rationale properties exist how human performance is turning into errors and safety issue (Sträter, 2005). Considering these properties can lead to proper system design.

Proper consideration of human aspects in system design needs – as for technical issues as well – a good data-basis. Events with human contributions are a very effective and appropriate source to identify human reliability issues, to generate appropriate human reliability data and herewith to generate most appropriate mitigation means (VDI 4006-3). The CAHR Method allows exploiting incident and accident data for human reliability design.

1.2 *The CAHR Method*

Events allow reflecting the dependencies between causes for human errors and providing herewith evidence for statistical soundness of a quantification approach. Even if event data might be seen as insufficient for generating quantitative statements in terms of human error probabilities as sometimes stated, they still can be used for proofing the underlying construct of human behavior or for proofing whether a distribution has transitive statements. Figure 1 provides the approach of generating statistical data based on the above-mentioned CAHR (Connectionism Assessment of Human Reliability) method. It was developed in nuclear and was applied to aviation as well as maritime and occupational safety events (Sträter, 2000).

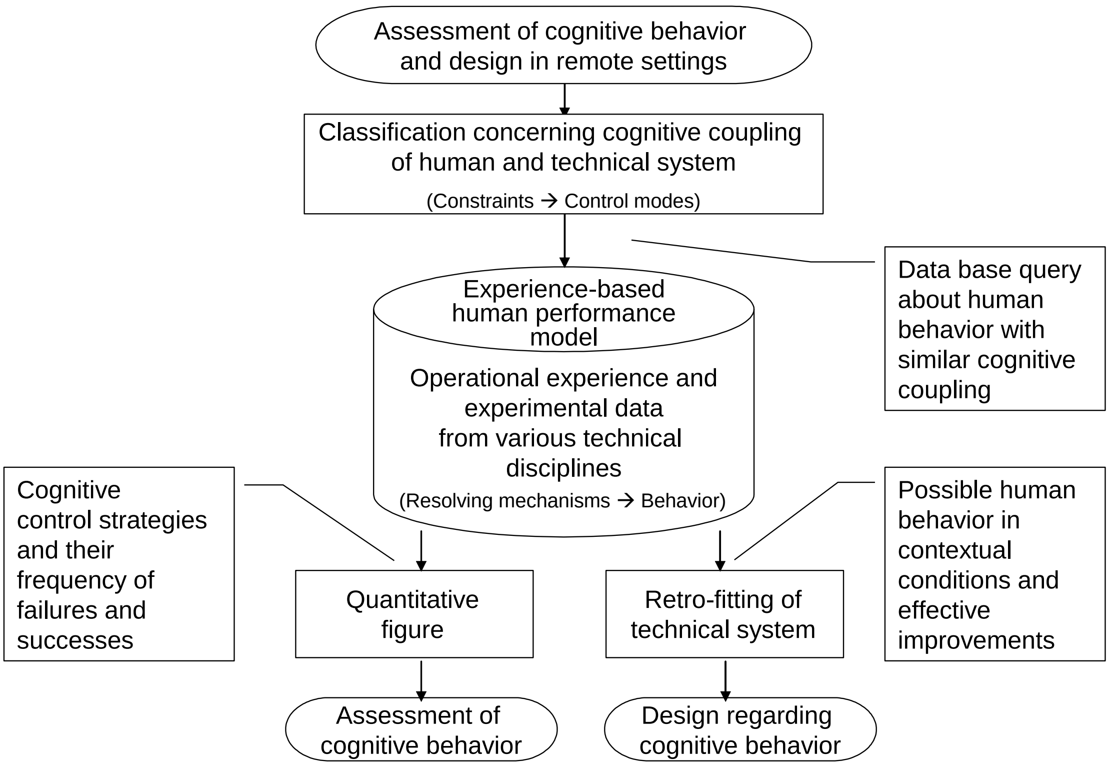

Figure 1 Approach for using retrospective incident data for prospective design and assessment

Event analyses may have quite different objectives (such as, for example, uncovering technical defects or points of organizational weakness, determining preventive measures or even apportioning responsibilities). In the case of events usually human, technical and organisational contributions as well as also their interactions are to be considered on different operational levels. The analysis needs also to consider the context in respect to the MMS and should not be focused on the acting individual. One of the most important aspects of event analysis ist to accept that the acting individual is not equated with the cause of the event and that the human at the sharp end should never be blamed for the event. Generally speaking, the Human involved in the incident / accident is a source of knowledge and the most knowledgeable person for the identification of the causes and most appropriate source to identifying the best mitigation means.

2 APPLICATION OF THE CAHR APPROACH EVENT ANALYSIS AND HUMAN PERFROMANCE ASSESSMENT

The CAHR method was used to analyze events from the German railway system (Arenius & Straeter, 2012). In total 142 events were analyzed. The task of leaving the train station was represented in 82 of the 142 of the events analyzed. These showed very important result for understanding problems when exiting a station.

In a majority of the cases, the train driver was identified as the person conducting the error by disregarding a "red light" intended to prohibit the train from leaving (for simplicity the term “red light” will be used for the description of a signaling requiring the train to stand still). The task "leaving the train station" in itself consists in leaving the train station when the signaling switches from “stop” to “go” (from red to green in car-driving terms). Thus, it requires the train driver to look at the signaling, notice the change and to accelerate according to the applicable speed limits. While seemingly a manageable task, the complexities of the task emerge at a closer look (Table 1).

Table 1. Most important Performance Shaping Factors (PSF) and their quantity for the event-type ‚Exiting the station‘.

PSF	*Description*	*Frequency of occurrence h*	*Relative frequency of PSF in the data-set h rel*	*Risk Management Index RMI=h*h rel*
Scanning of signaling	Scanning of signaling is not accomplished appropriately	54	0,71	38,34
Distraction	High distraction due to the number of signals and other information to process (e.g., passenger actions)	45	0,80	36,00
Irregularities	There are Irregularities in the event situation	44	0,57	25,08
Work experience	Lack of practice	22	0,69	15,18
Cooperation	Lack of coordination between train driver and others (dispatcher, train personnel)	9	0,69	6,21
Stress	Stress due to workload	7	0,64	4,48
Time-pressure	Time-pressure, e.g., due to delay	5	0,71	3,55
Authority	Train driver follows instruction, which were placed on him but are not fully informed about the local situational conditions	5	0,63	3,15

The table first shows the top 8 PSFs and their frequency of occurrence (h) in the event type 'Exiting the station'. The forth column depicts the relative frequency of occurrence (h rel). This figure is calculated by the frequency of occurrence (h) in the event type divided by the total number of PSFs in the train data set. A high h_{rel} means that the PSF is closely related to the event type. The lower h_{rel} the less this PSF is attached to this event type. From both figured a Risk Management Index RMI=h*h_{rel} can be calculated: the higher this value is the more this PSF is of importance for the event type. The RMI can be used to determine the most important factor that needs to be managed in a safety management approach.

As events are usually triggered by a set of different contribution factors, another calculation can be made to show the interrelations of the PSF, i.e., the frequency of common appearance in an event (cf. VDI 4006-3). An NMDS (Non-Metrical Multidimensional Scaling) can be made to generate a graphical representation of these interrelations. Figure 2 shows the NMDS of the PSFs from the table above for the scenario ‚Exiting the station'. The closer the PSFs are in the drawing, the higher is the interrelation (common appearance) of the PSFs in the events. Very prominently, the combination of Irregularities, Scanning of signaling and Distraction is a critical combination for the event type ‚Exiting the station'.

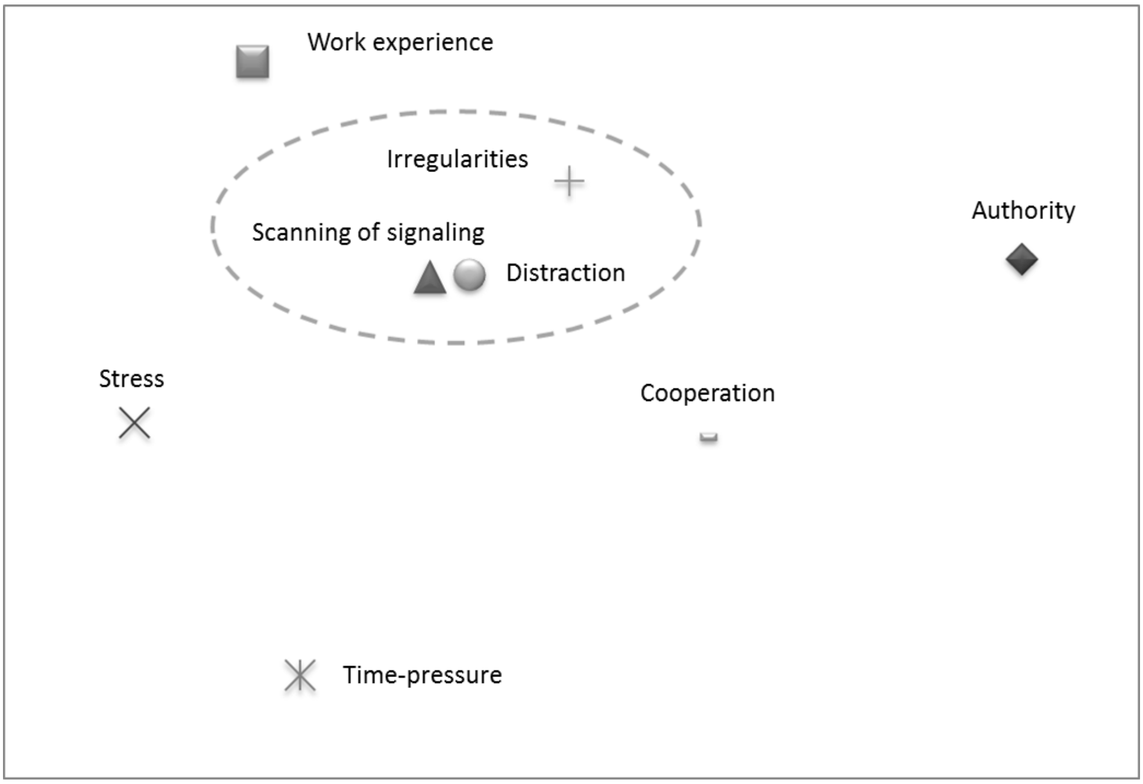

Figure 2 NMDS of the PSF in the event-type ‚Exiting the station'.

Overall, the evaluation of the events shows the following typical setting for the event-type ‚Exiting the station':

The train driver has to deal with time pressure resulting from delays, with incomplete or false information coming from other parts of the system regarding the readiness of the train for departure (e.g. from on-board staff), irregularities stemming from other parts of the system requiring the train driver to disregard the scheduled departure time, distractions by e.g. passengers asking for information or incompatible tasks requiring visual attention at the same time. Furthermore, as the correct scanning of the rail-side signaling is a vital competency of the train driving task, the fact that this competency could not be applied to the situation suggest improvement potential regarding the content of the training of train drivers (from the event descriptions it can be concluded for instance that that train drivers also check whether the passengers stay clear of the train when it is leaving). This requires continuously monitoring of the trackside vicinity in the station.

In consequence, two cognitive demands can be denoted as an inherent incompatibility between two tasks: The visual monitoring of signals ahead and the visual monitoring of the track vicinity when leaving from the station. Furthermore, the analysis showed that the monitoring of the passengers in the vicinity of the tracks poses high cognitive demands (Arenius et al., 2011). Due to the long breaking distance, the train driver has to prospectively infer how the people will move in relation to the train and if they thus risk coming to harm when the train leaves the station.

3 DESIGNING SYSTEMS ACCORDING TO HUMAN BAHAVIOUR

3.1 *Intended effectiveness of the Human*

Looking at the event-type, the behavior observed cannot be interpreted as error because the train-driver has good reasons to perform as observed in the events:

For all events, the train driver did not notice the signaling or noticed the wrong signaling as a result of the approximations and associated actions in context. However, normally, this would have constituted efficient behavior: The train drivers usually follow the schedule for departures as displayed in the train cockpit. Normally, the train departs from the train station when the scheduled departure time is due. As train stops occur frequently with the train usually leaving according to schedule, there may be a strong, habituated association between the scheduled departure time and the corresponding action of accelerating the train. Furthermore, contextual factors (e.g. time pressure, distractions, incomplete/wrong information) may reinforce the train driver to adopt this behavior to cope with the given the situational demands. The approximation to skip the look ahead at the signaling and accelerate directly may add up to a significant amount of time saved if there are a lot of scheduled stops on the route. Thus, the train driver frees up capacities to deal with other matter requiring attention, e.g. the monitoring of the track-side vicinity for travelers approach the train. As long as the train departs at scheduled time, the behavior will always be effective.

3.2 *Task- vs goal-related behavior*

VDI 4006-2 therefore makes the important distinction of task-related behavior and goal-related behavior to describe this aspect of intended effectiveness of humans in working environments (cf. also Woods et al. 2010):

- Task-related behavior: In the task-based assessment it is assumed that the task and the way how this task can be accomplished is the only aspect the Human intends to achieve in the given situation. Activities are processed on the basis of known routines or prescribed statements. There is no decision needed to decide for the tasks or to execute it. The task-related perspective assumes that the person has only to do this task as a stand-alone task. Other system requirements, which act in the same time, are not present or neglected.
- Goal-related behavior: Task completion requires a decision-making processes. Such decision-making can include the identification of the task itself (recognizing that a certain task is to be performed), the choice between several parallel tasks to be performed (prioritizing tasks), or the way to do a certain task (choice between alternatives). The goal-related perspective takes into account that a person first has to match and evaluate various alternatives based on several goals and objectives existing in a working environment, in order to generate the best action. In such adjustment processes wrong decisions can be made that lead to an action is performed, which is not optimal for the security of the system and may have a negative impact on the safety performance of the system.

If there exists goal-related behavior, the use of a technical barrier is always seemingly effective. However, as it does not solve the goals conflicts in the system, the means will remain ineffective in practice. Implementing will rather increase the goal conflict for the Human as hence the cognitive demands will increase and the error mechanism will not be eliminated.

Therefore VDI 4006-2 suggests building means that eliminate goals conflicts in the system rather than building up complexity. Otherwise cognitive demands will rather increase than decrease. A valid derivation of measures may only take place if the connection between successful and unsuccessful behavior is understood, that is, if the measure is clear in how both unsuccessful behavior is reduced while successful behavior is increased. Both are equally important for system safety and one cannot be understood without the other.

4 ACKNOWLEDGEMENTS

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