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A Practical View on Integration of Risk Management and Human Factors

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The present paper explores the integration of risk management and human factors through a proposed model that operationalizes mapping of interfaces through structure driven risk management combined with Human Factors analysis. Furthermore, the model will be discussed using a developing case published by the Danish train operating company, Danske Statsbaner (DSB), to explain the integration model with a tangible example as well as showcase the relevance of the integration model. The framing and exploration of decisions through an integrated model for risk management and human factors allows mapping implicit interfaces more explicitly and creates a clearer overview of upsides and drawdowns of decisions, informing decision makers to a higher degree.

Keywords: Risk management, Human factors, Integration model, Risk assessment, Human-centred design

1. Introduction

Traditionally, Human Factors and Risk Management have been two independent disciplines. However, there is research that have examined how the two disciplines overlap and complement each other, e.g., Rasmussen (1997). Risk Management is typically utilized on a management level in terms of assessing uncertainty and impact of uncertainty on objectives, but also involve operational aspects in terms of implementing risk constraints, performance strategies, sustainability etc. This is equivalent to the upper layers in Rasmussen's Risk Management Framework (1997). Focusing on the operational conditions, there are direct parallels to the Human Factors field which involve analysing and improving interactions between humans, technologies and processes – the bottom layers according to Rasmussen (1997). Both disciplines have strong sets of recognised strategies and tools that can create resilience and capacity of processes, technologies and changes and ensures that the human element of skills and re-sources as well as robust infrastructure and financial risk is built into the resilient system from the start.

This paper seeks to combine existing tools and explore them from a practical perspective. Utilizing Risk Management and Human Factors in combination can lead to a promising methodology and/or framework that solves challenging tasks. This can be achieved by integrating and harnessing the existing tools from the two well-established disciplines.

By integration we refer to the harmonisation of definitions, and language, but also to the situation, where Risk Management and Human Factors is practiced as separate disciplines anchored in separate areas of domain knowledge. In the later situation risk and risk assessment is a natural element of Human Factors work, and Human Factors issues can materialise as risk during risk analysis, but such practice leads to double work and silo-work.

By utilising each of the fields' resources in a more united and efficient way, it is possible to transition away from the silo-oriented approach of working independently or the strategy of employing simply one or the other discipline and instead integrating the two fields.

This paper presents a detailed definition of Risk Management and Human Factors, respectively and then discusses their integration. To showcase the contribution and integration of combining the two fields, a realistic example will be used to discuss the application in an operation context. Furthermore, we present the integration model as the foundation of combining Risk Management and Human Factors.

2. Background

2.1 Risk management

Risk management is applied across a wide range of domains in all industries in which actors must weigh alternatives under uncertainty and make decisions that affect performance and outcomes (Hubbard, 2025; Aven, 2024). Its wide application across technical, operational, financial, and organizational contexts creates variation in how key terms are interpreted and operationalized, which can reduce consistency and comparability across risk assessments (Hubbard, 2025; Aven, 2024; BCBS, 1988, 2004, 2017). A common vocabulary is therefore important for rigorous discussion, interoperability of methods, and transparent communication across stakeholder groups and lifecycle phases. For this reason, the definitions and principles in ISO 31000 are used, in this paper, as an anchoring reference for terminology and baseline alignment. ISO 31000 defines risk as *the effect of uncertainty on objectives* and defines risk management as *coordinated activities to direct and control an organization with regard to risk* (ISO 31000). The standard also states as a fundamental principle that *a structured and comprehensive approach should be used and contributes to consistent and comparable results of risk assessments* (ISO 31000).

To augment the ISO 31000 definitions with an explicit structural logic, the concept of structural risk (Jensen et al., 2012; Jensen, 2017) is introduced as a lens for analyzing how uncertainty affects the way objectives are achieved through structural analysis. Supporting a concrete and auditable representation of structural analysis, structures of an organization are defined in accordance with the 'asset' definition of ISO 55000. An *asset is an item, thing, or entity that has potential or actual value to an organization*, and assets may be *physical or non-physical* (ISO 55000). Building on this definition, and explicitly as an operational extension for risk analysis, assets encompass not only physical items and systems, but also the processes, activities, and resources that enable an organization to achieve its objectives. This extended definition is used to ensure that risk identification is not limited to engineered artifacts but covers the full set of enabling and constraining structures relevant to lifecycle decision points. This implies that risk assessment is performed with an explicit boundary definition that can be selected according to its purpose. Within this boundary, risk scenarios can span technical, commercial, and administrative domains because the effects of uncertainty on objectives are typically mediated through coupled decisions, dependencies, and constraints across those domains (Jensen et al., 2012). To operationalize risk identification and communication in a structured manner, the delivery of objectives is organized into work (work packages, activities, functions, and decision tasks) performed on or through the relevant structures and assets.

A distinction is also maintained between (a) risk as an effect on objectives and (b) risk sources, events, and conditions that generate or shape uncertainty. Events or phenomena outside a selected boundary are considered as external risk sources or external conditions that can influence work and asset performance within the boundary. They are not excluded from consideration but are represented explicitly as exogenous drivers in scenarios. Similarly, internal conditions, such as inadequate assumptions, incomplete knowledge of structures, mis-specified requirements, weak interface definitions, or insufficient control of change, can create vulnerabilities that amplify the effects of uncertainty.

In this approach, "inherent risk" is used as an explicit category for sources of uncertainty and pre-control conditions that are relevant to a selected boundary and objective set. It is treated as an input to scenario construction rather than as a synonym for risk itself (FORCE Technology, n.d.) Because the term "inherent risk" is used differently across disciplines - for example, as “risk before controls” in audit contexts - the intended meaning is defined explicitly to avoid ambiguity. This framing supports systematic identification of interfaces and decision points where uncertainty can be introduced, spread or amplified.

2.2 Human factors

Human Factors is a scientific and practical discipline, based on psychological research and research from other disciplines including sociology, anthropology, engineering, philosophy, etc. (Wickens et al. 2015). Focus is on the interaction between people and technology, environments, organisations, tasks, and processes (Karwowski, 2005) as well as interaction between people, such as collaboration, leadership and team dynamics. (Flin et al., 2008; Koester, 2007). The Human Factors discipline creates knowledge from studies and experiments and uses this knowledge as input to design processes, technology development, organizational programs and other interventions (Sanders & McCormick, 1993; Reason, 1997). The goal is to improve overall system performance, safety, user experience, and wellbeing, e.g., through creating better usability and more meaningful interactions between people and technology (Dul & Neumann, 2009; Norman, 2013)

In relation to safety, the perspective of Human Factors has changed over the last two decades. From focus on the individual to focus on the system. From focus on human error to focus on human performance, both positive and negative. This paradigm shift is also known as “The New View” (Dekker, 2011, 2014; Hollnagel et al., 2015). Earlier, people were seen as “the weak link” in systems. Now, they are seen as a capacity which is making the system resilient. Systems are becoming more complex, which again means higher variability (Perrow, 1999; Rasmussen, 1997). When people are seen as a resource and not a problem to control, they are able to compensate for these variations, fill in the gaps, and thereby maintain safety even when there is lack of resources, uncertainty or inadequate procedures and tools (Dekker, 2014; Koester, 2024).

Human Factors cover a huge repertoire of tools and methods. From ethnographic observations of work processes and group dynamics to experimental evaluation of interactions between users and technology. Experiments and observations play a key role in Human Factors but also verbal self-reporting – such as interviews and discussion – and techniques such as eye-tracking are widely used (Stanton et al., 2013; Salvendy 2012; Wickens et al., 2015). Often, Human Factors deals with two perspectives: (1) The user centred perspective, where focus is on specific user groups, their user needs and context of use (ISO 14-210). And (2) the human centred perspective dealing with more generic psychological mechanisms involving any human, therefore also any user, such as perception, attention, and memory (Wickens et al., 2015; Norman, 2013). Combining the practical knowledge about specific user groups with the general and more theoretical psychological knowledge about humans in general is a core principle within Human Factors. Additionally, the user centric approach includes involvement as well as co-creation with user representatives in the process. This can be regarded as “designing with users for users” (Bødker, 1987; Schuler & Namioka, 1993; Culén & Gasparini, 2013). Involving the user from an occupational setting as co-creators of their own work conditions leads to higher sense of ownership which again leads to motivation and wellbeing. This can be applied to not only technology in the workplace but also to processes, workflows and organizational design (Parker & Wall, 1998).

3. A model for integration of Human Factors and Risk Management

Risk Management and Human Factors are frequently linked in safety-critical practices and research. The contribution in this paper is not to claim novelty of the linkage itself, but to present a boundary-defined and terminology-consistent integration model that showcase how the two disciplines interact and communicate with each other. A known concept that can exemplify the commonality between the two fields is Capacity which, in Human Factors, describes the process of building human capabilities and characteristics into the system from the start making it safe in case of failure (Hollnagel, 2015) et al.) In Risk Management, analysis of a system, for example during development, will first test the strength of assumptions regarding its design and then improve on deficiencies in those assumptions through implementation of control strategies.

The integration of Risk Management and Human Factors is based on a shared structural starting point. In Risk Management, structures are defined through assets within a selected boundary. Risk is described as breakdown of work performed on or through these structures. In this framing, “inherent risk” refers to risks that are naturally associated with a strategy, situation, process, or system. Inherent risks and threats are systematically organized in an Inherent Risk list, which supports consistent identification of causes across structures and decision contexts.

The Inherent Risk list functions as a structured catalogue of typical breakdown mechanisms. It is not a complete risk assessment in itself, but a systematic starting point for reviewing assets and work. By linking identified causes to predefined inherent risk categories, the organisation moves from a general or philosophical discussion of uncertainty to a concrete and engineer-like analysis of how work can break down. Risk descriptions are then structured into causes, risk event, and consequences within a defined boundary and with a clearly identified risk owner and risk payer.

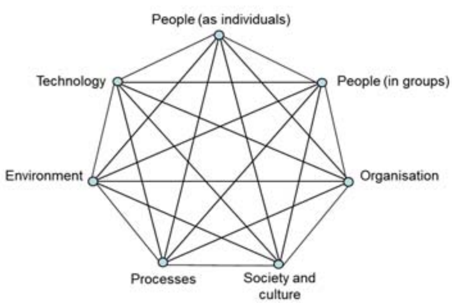

Figure 1. SEPTIGON-framework (Koester, 2007).

Human Factors similarly considers a set of elements as a starting point but further focuses on interaction within and across structures. The SEPTIGON framework (Figure 1) illustrates the relevant elements in interactions and how they influence each other. While the integration model does not depend on SEPTIGON specifically, it reflects the same principle: work and interaction must be structurally mapped before they can be analysed and improved. Human Factors contributes with discipline-specific methods for analysing perception, attention, workload, communication, roles, and workflows within the defined boundary.

The integration model shown in Figure 2 aligns these two systematic approaches. Risk Management provides the boundary definition, the objective framing, and the initial high-level identification of inherent risks affecting the asset. Human Factors then analyses the work and interaction conditions associated with these identified risks, using structured methods and data. The insights from Human Factors are subsequently fed back into the risk assessment, where probability estimates, consequence descriptions, and mitigation strategies are refined.

Figure 2. The Risk Management and Human Factors Integration Model.

Risk Management serves as the overarching structure for documenting breakdowns and consequences, while Human Factors provides depth in understanding and improving interactions and processes. The result is a coherent and iterative process with explicit interfaces where Risk Management and Human Factors exchange information, share terminology, and create alignment across tools and professional domains.

The integration model facilitates opportunities to integrate more subject-matter and discipline-specific content into the risk assessment. This is to ensure the human element is included, to decrease subjectivity and ensure a more specific and less vague risk assessment. Risk Management is regarded as a managerial tool and is recognised throughout the organisation, from the operational level to the management level. The tools within Human Factors are of particular relevance in the context of the discipline-specific content such as the interaction between operators and technologies.

Accordingly, Risk Management outlines the overall landscape after which Human Factors further clarifies and provides insight into which tools can be used to mitigate the risks initially identified by Risk Management. Subsequently, the Human Factors insights provide input for the refinement of risk assessment in which the initial risks get updated and specified. Incorporating the Human Factors inputs in the revised risk assessment provides the basis for potential mitigation strategy and further builds basis for informed decision analysis to support management decisions. This process forms an iterative cycle structure as visualised in Figure 2 and illustrates Risk Management as a function that offers a high-level overview across all levels of the organisation, from management to system operations, and represents the management competence. This function provides a general risk assessment of the asset and process in question and maps potential causes and consequences.

Human Factors is then utilised as an instrument to process and enrichen the initial overview and present a more specified analysis of the causes based on discipline-specific knowledge and data. Furthermore, the Human Factors function in the integration model denotes the professional experts and contributes with solutions and recommendations that allow for development and improvement. With an iterative approach, the output from the Human Factors function then informs the third component in the integration framework. The initial risk assessment is updated and further specified with revised probability estimates. A clear and well-defined mitigation strategy is then developed, building on Human Factors methods as risk mitigation tools.

The integration model demonstrates how Risk Management contributes by providing and defining the problem description and identifying pertinent challenges and risks. Human Factors subsequently adds value by not only conducting an in-depth mapping of the process but also by formulating and presenting solutions to the identified challenges and risks which is then reassessed by Risk Management. To demonstrate the integration model a realistic scenario is established as an example, grounded in common knowledge about the Communication-Based Train Control (CBTC) system and the public available descriptions of the upcoming GoA 4 automation of the Copenhagen railway network. The scenario is related to passenger experience and the design of passenger journeys.

4. The scenario: Passenger experience with flexible use of tracks

The operator of the public transportation local train system in Copenhagen, Denmark (DSB), is planning a major transformation from Grade of Automisation 2 (GoA 2) to GoA 4. This means that trains will no longer have train drivers monitoring passenger flow and initiating departure from the platforms. The aim of the project is to increase the capacity and performance of the system to be able to transport more passengers using the existing infrastructure of tracks and stations. This means that DSB – over a 15-year project period – will acquire automated trains and put them into service (DSB, n.d.). Moreover, it means that several other systems, so-called “Supporting System”, will be designed and implemented to support the new driverless concept. Some systems will replace existing systems, and other systems will introduce new functionalities (MERCELL, n.d.) including Equipment for S-Network (Future S-trains). Introducing the new GoA 4 includes introduction of new roles and responsibilities on the operator side, some roles will change, tasks and workflows will be different. Further, the train driver role will disappear, and the related functions will be taken over by automation and personnel in a control centre. New technologies and workstations in the control centre means new interactions between operators and the technology. The passenger experience will also change, which will be supported by new systems giving information to passengers and providing two-way communication between passengers and the control centre in cases of e.g. emergency situations. This introduction of new technologies, new or changed roles, new workflows and changes in passenger experience alters the decision landscape which will introduce new risks and change the configuration of risks compared to the existing system for all participants. This highlights the need for both risk management and human factors integration throughout the project from initial designs to final verification of requirements.

It is assumed that the GoA 4 system shares the same fundamental capabilities which are already embedded in the existing GoA 2 system called CBTC but not necessarily utilized in daily operation as it is today. One essential capability in this context could be the system's ability to optimize schedules by driving trains flexible on both tracks instead of a conservative right track driving pattern, thereby optimizing the use of the tracks. This could for example be an advantage in peak situations (rush hour) where there might be a higher number of trains travelling in one of the directions towards or away from the city centre compared to the other direction. This functionality is, even if it is available today in CBTC, not utilized, but it could become relevant as a feature in the transition to GoA 4 because it can optimize the capacity of the system even further making it a better business case.

Step 1 – The initial high-level risk assessment

The integrated Risk Management and Human Factors approach would start with an initial high-level risk assessment, which, in this case, could look like this:

Risk description: Frequently failed guidance of passengers to trains, resulting in an impaired transport experience for the passengers, as they board wrong trains (direction) during flexible track usage. This risk already exists in the existing CBTC system, and the consequences are the same, but the frequency will increase dramatically if flexible use of tracks is introduced with the transition to GoA 4 to optimize the performance of this new system.

Causes: (i) Variable platforms due to compact train schedule confuse passengers, (ii) Frequent last-minute platform changes, (iii) Several trains present at adjacent platforms simultaneously, (iv) Information systems not aligned with the different user-groups (passengers with special needs).

Consequences: Product perceived less valuable by customers/users. Slower uptake of expected passenger growth. Bad press.

Step 2 – The detailed Human Factors Analysis

The initial high-level risk assessment maps out some issues and consequences which calls for further analysis, the detailed Human Factors analysis. This analysis will reveal that flexible use of tracks means that trains will not always depart from the same platform at the stations, therefore passengers cannot rely on routine alone. They must search for departure information, perceive this information correctly and act accordingly which requires a higher level of attention and situation awareness compared to a conservative schedule where trains can be expected to depart from the same platform every time. Passengers will, if their perception-decision-action process fails, suffer the risk of boarding a train travelling in the opposite direction or towards another destination than intended because some, but not necessarily all, trains will leave from different platforms than normal and expected. The passengers will be delayed and probably also frustrated, i.e., having a bad passenger experience. The circumstances will be particularly difficult for those passengers traveling with bicycles, luggage or in groups such as families and school groups. These are the consequences as seen from an individual passenger perspective. Further, when this happens repeatedly and for many passengers, it can, as consequences on system level, lead to complaints, bad reviews, loss of customers (passengers) and ultimately loss of reputation for DSB.

The scenario can be analysed using the SEPTIGON framework mentioned above and shown in Figure 1 (Koester, 2007). Passengers (people as individuals or in groups) navigate and find their way (process) at the stations (environment) using passenger information systems, signs, and other forms of visual guidance (technology). Successful wayfinding depends on both individual factors and the smooth interaction between people, environment, technology, and process. Any friction in this interaction may lead to a negative user experience.

DSB (organisation) is responsible for designing the technological and environmental elements that shape and support the wayfinding process. In addition, passengers' perception and expectations are influenced by cultural norms (society and culture), such as the widely understood convention of right-side traffic in Danish rail systems.

In this scenario, the SEPTIGON framework is used to highlight the critical elements of the system and to analyse and describe both successful interactions and potential areas of friction.

Based on these causes and consequences, found in the analysis of the problem, the Human Factors analysis will continue into the solution space. Here, focus is on articulating a mitigation strategy that activates relevant Human Factors tools and interventions. From a Human Factors perspective, the mitigation strategy would be designing audio visual passenger information such as signs, screens and PA messages to guide passengers as seamlessly as possible to the right platform. Focus will be on usability for all passengers as well as accessibility for passengers with special needs. The design will be based on and informed by analyses of passenger perception and action seen with the passenger journey as overall context. It will also be based on iterative usability evaluations of solutions, from mock-ups and early low fidelity prototypes to validation studies of the final design. It can for example be relevant to include eye-tracking studies for a deeper understanding of passengers' visual perception of signs and screens, and it can be relevant to look at and minimize use errors based on experiments using a full-scale simulation environment.

In addition, it could be relevant to examine how the mindset of passengers can be changed from boarding trains based on automated and routine-based (System 1) decision making to a deliberate and reflective (System 2) decision. Passengers will need to adopt a reflective approach to their train journey instead of a routine-based approach. Visual and auditive cues at relevant touch points in the station environment can, through a structured Human Factors process, be designed to prompt passengers, trigger their reflection and thereby stimulate awareness. Alternatively, passengers will need to build a more complex mental model taking the occasional flexible use of tracks and platforms into account and base their decisions and actions on that model. This alternative model will require higher mental efforts and result in a higher mental workload for the passenger. But it will also require a foreseeable pattern of flexible driving, a "new normal", for the passengers to build corresponding mental models, e.g., fitting their own personal schedules and daily routines related to for example commuting.

Step 3 – Revised risk assessment

The Human Factors insights inform the initial risk assessment and allow for focused scenario building, data collection and quantification for weighing of decision options regarding running trains flexible across platforms during peak hours against the objective of successfully establishing fully automated trains. Assuming the objective of management is to establish a fully automated rail program that can run more efficiently, cost effective and with the same level of safety as the current system while also being a success that is chosen by customers. In this scenario and framing, the main decision management needs to weigh, is if the increase in efficiency of time schedules is worth the cost of trains arriving at platforms in an – for the passengers – unpredictable pattern and the potential passenger confusion and delays that might generate. With the insights from human factors, management can utilize risk management to a greater degree to explore the cost basis of implementing control strategies for mitigating the effects of flexible train arrivals at platforms. Here the increase in revenues and satisfaction from a more efficient timetables must be held against the consequences of the flexible trains and cost of control strategies and further compared to a scenario where conservative right track driving pattern is used.

This further posses' questions which management must weigh before deciding on how to configure the system for an outcome which closest align with their objective to establish a safe and successful, fully automated rail program.

5. Conclusion

We have illustrated how the proposed 3-step Risk Management and Human Factors integration model can be used through a scenario of flexible use of tracks and platforms in a fully automated local train system. The framing and exploration of the decision to run trains flexible to station platforms through an integrated model for Risk Management and Human Factors allows mapping implicit interfaces more explicitly and creates a clearer overview of upsides and drawdowns of the decisions. This increases the information available to decision makers prior to making decisions and can improve the potential outcomes of decisions and decision strategies.

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