Humans: trouble, or treasure in the eyes of EN 50126-1:2017 Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS).

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Abstract

This research addresses human error and the process standard EN 50126 Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS).

In Norway, it is required by The Railway Infrastructure Regulations to use the standard for new construction or changes to subsystems in the infrastructure. The standard is a harmonized standard which means that it provides presumption of compliance with requirements in relevant legislations. The standard aims to ensure continuous control of all aspects of Reliability, Availability, Maintainability and Safety (RAMS), by a consistent management. Clause 5.6.4 Human factors in the EN 50126-1:2017 provides information about human factors and is the starting point of my document analysis.

The question is how the information about human factors and human errors is explained. Is this information sufficient to be able to understand the topic of human error?

Based upon the checklist in clause 5.6.4 Human factors, I carried out a document analysis where I used the checklist as a lens to explore the topic of human error.

The standard has been published in two editions, where risk assessments are addressed in a part 2 of the EN 50126-2:2017. Much of the fundamentals on which the standard rests upon have not changed. The division of risk assessments as a separate part, contributes, with its structural focus to human factors being taken out of the assessment. Between the first and the

second edition of the standard, the railway sector has undergone major changes and regulations have been updated. This development is not easily reflected in the standard.

A fundamental objective of the standard is to contribute to a standardized process for managing RAMS. Its descriptions of the “V-model" as a management model combine three dimensions and it is up to the user to choose which one is emphasized.

The way human factors and errors are addressed, can lead to the assumption that using the checklist is all that is needed to derive human factors. The implication can thus be that human issues are taken too lightly, and we miss out on measures to optimize the system.

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Contents

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To my daughter

Hilde Kristin Gjendalh

and my grand children

Tobias Gjendalh and Sofie Amalie Gjendalh

List of tables and figures

Abbreviations and expressions

ATS	Activation Trigger-Schema
CEN	The European Committee for Standardization
CENELEC	The European Committee for Electrotechnical Standardization
CIEHF	Chartered Institute of Ergonomics and Human Factors
CSM	Common Safety Methods
CST	Common Safety Targets
EEC	European Economic Community
ERA	European Railway Safety Authority
EN 50126:1999	EN 50126:1999 Railway applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS)
EN 50126-1:2017	EN 50126-1:2017 Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) Part 1: Generic RAMS Process
EN 50126-2:2017	EN 50126-2:2017Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) Part 2: Systems Approach to Safety
HFES	Human Factors and Ergonomics Society
IEC	International Electrotechnical Commission
IEA	The International Ergonomics Association
JBV	Jernbaneverket (Rail Infrastructure Manager)
NEK	Norwegian Electrotechnical Committee
NOU	Norwegian Public Assessments
NSB	De Norske Statsbaner (Rail transport operator)
RAMS	Reliability, Availability, Maintainability and Safety
SJT	Statens Jernbane Tilsyn (Norwegian Railway Safety Authority)
SPAD	Signal Passed at Danger
TSI	Technical specification of Interoperability

This thesis is about human errors and how these are expressed in a rail safety standard. The research is based upon the information about human error provided by the process standard *EN* 50126-1:2017 *Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) Part 1: Generic RAMS Process*.

The railway system has been around for approximately 200 years and has always been important for transportation of people and freight, and economic growth. The first Norwegian railway was the Hovedbanen between Christiania (Oslo) and Eidsvoll which opened in 1854. The first Norwegian Railway Act was constituted in 1848, mainly due to an application from the British Consul General in Norway for a license to build a railway between "Christiania, Øieren and Mjøsen".

The application was made to obtain permission to expropriate land, the exclusive right to build tracks on the section in question, preferential right to build side tracks and exemption from customs duties. The Norwegian Ministry found that there was hardly any reason to give private individuals the right to expropriate another man's private land.

The Railway Act of 1848 was made general and with a right of redemption for the state. This was to not pre-empt a possible decision on the question of whether there should be an opportunity for private individuals to build a railway, or whether this should be done by the public sector.

Safety has been an important issue of the railway system right from the start. Main concerns of the Act were the duties and rights towards securing that the railway was build, was of social usefulness as well as the King's authority to give additional regulation for safety.

Today, an important way to ensure railway safety, is the use of the standard EN 50126 when building new railway lines or renewal of existing lines. According to the foreword of the standard its aim is to:

> "provide railway duty holders and suppliers, with a process that enables the implementation of a consistent approach to the management of Reliability, Availability, Maintainability and Safety (RAMS). Human factors are a core aspect within an integrated RAMS management process." (EN 50126: 2017-1, p. 32).

In Norway it is a legislated requirement to use the standard. This is a requirement in the Norwegian regulation by The Railway Infrastructure Regulations § 3-1. General Requirements for Railway Infrastructure.

> "Infrastrukturforvalter skal benytte prosesstandarden EN 50126 ved bygging av ny jernbaneinfrastruktur og ved endring av programmerbare tekniske systemer. Ved andre endringer av jernbaneinfrastruktur skal infrastrukturforvalter vurdere om endringen er av en slik karakter at bruk av EN 50126 er hensiktsmessig. Vurderingen skal dokumenteres."

There is no official translation of above the passage into English. My unofficial translation below:

> "The infrastructure manager must use the process standard EN 50126 when building new railway infrastructure and when changing programmable technical systems. In the case of other changes to railway infrastructure, the infrastructure manager must assess whether the change is of such a nature that the use of EN 50126 is appropriate. The assessment must be documented."

There is no clear rule for what constitutes as major or minor renewal of infrastructure. This has been and are an ongoing discussion, it must be decided in every case. Generally, maintenance work and rebuilding after accidents or damage that has occurred due to climatic conditions are not considered as major renewals. Changes which require specific intervention of the relevant safety authority, such as a new authorization for placing into service, or a revision/update of the safety authorization of an infrastructure manager would be considered as major renewal. In most cases the decision is based upon a discussion between the infra structure manager and the National Rail Safety Authority (SJT). In cases of disagreement, it is the National Rail Safety Authority who makes the final decision. In other words, the standard is of vital importance when building new infrastructure or major renewals of old infrastructure.

Thesis question

Human error

From the 1970s and onwards safety scientists began to study the topic of human error, inspired by the burgeoning field of cognitive psychology. Encountered with several adverse events and accidents, the topic of human error became central in safety science in the last decades of the 20th century (Le Coze, 2022 p.1).

Read et. al. (2021) shows that current science holds a wide range of different perspectives and theoretical frames on human error. If human error is considered as the cause of a system fault or in the worst case, an accident, it represents a stopping point to the consideration of why an accident happens. There is no way to go from the fact that the operator closest to the event is to blame for the negative outcome. The human failed with their task.

Another way of looking at human error is to consider it as a process, that is the error itself. This can according to Woods and Cook 2012 (cited in Read et. al. (2021)) be considered as a departure from a good, correct and truthfully way of doing things. A major issue with this is when it is considered that if only the human had done it correctly the accident would not have happened. The problem with this approach is that this does not consider the actual situation, but an imaginary truth based upon the knowledge of the outcome. This is highly influenced by hindsight bias.

Human error can also be confounded with its outcome, where the error is defined in terms of its consequence. The human error is then viewed as the accident, or the adverse event itself. For example, a train driver passing a stop signal, an event named "Signal Passed At Danger" (SPAD) within the railway industry. The consequence of the adverse event is passing the signal, and the focus lies upon the train driver's ability to comply with the signals.

Standards

According to Hayes (2022) standards, codes and guidelines are a key source of information about safety. Standards need to be taken seriously by their audience, which means that standards must obtain credibility and legitimacy. This is achieved through the process of preparing and revising standards. This is a multi-stakeholder process where a draft is developed and further developed by feedback from the relevant industry. The draft is then modified until consensus is achieved. Standards are viewed as best practice rules, written up by the profession's experts and constitutes as voluntary set of rules to be complied with. The fact that standards are developed by experts of their aera also means that they may reflect the views of the profession. (Hayes, 2022)

Regulative bodies like the Ministry of Transport, and the National safety authorities capitalize upon the industry's own development and valued reputation to enhance compliance. In this way authorities can rely upon the industry for rules that manages safety.

Olsen (2020) states that the relations between risk and standards are scarcely systematically analysed. There has been limited research on the role of standardisation and use of standards in risk governance. "The possibility that such standardisation might produce other risks due to inherent dilemmas and paradoxes has virtually not been tested." (p. 4)

Ingvarson & Hassel (2023) undertook a document study of the amount of research done towards standards and their effect. Even if the level of detailed risk management regulations represented in standards, standardisation of risk management are met by critical voices who indicate that analysis of the effect or value of applying risk management processes with different levels and types of standardisations are not readily available in the research literature. The authors suggest that the strong positions of standards are based upon a practical consideration rather than empirical data on effects of standardisation.

The EN 50126 standard describes a process that aims to ensure continuous control of all aspects of Reliability, Availability, Maintainability and Safety (RAMS), by a consistent approach to the management of RAMS.

According to EN 50126, the RAMS performance of a railway system is influenced by sources of failures introduced internally within the system and imposed on the system during operation and maintenance activities. Failures in a system are categorised as random or systematic failures. Random failures are due to causes which can be described by statistical distributions. Systematic failures are failures due to errors in the system life cycle activities which causes the system to fail deterministically under particular combinations of inputs or under particular conditions. Systematic failures are mainly caused by human errors in the various stages of the system life cycle. (EN 50126-1:2017, p.27)

Which human and other factors could influence the RAMS performance of the system needs to be identified and assessed. In order to create a dependable system, the cause and effects of the influencing factors should be managed throughout the life cycle of the system, by application of appropriate controls to optimise system performance.

The EN 50126-1:2017 consists of the main part (Clause 1 to Clause 8) and Annexes A, B, C, D and ZZ. The requirements defined in the main part of the standard are normative, whilst Annexes are informative.

According to the standard, clause *5 Railway RAMS* outlines the body of knowledge on the subject of RAMS needed for users of the standard to be able to fully understand what is required to comply in an appropriate way. Subclause *5.6.4 Human factors* focuses on human factors influencing railway RAMS performance. These factors and their effect should be derived as they are input to specifications for establishing the targets of RAMS-requirements.

EN 50126-1:2017 defines human factors as: "The impact of human characteristics, expectations, and behaviour upon a system. These factors include the anatomical, physiological, and psychological aspects of humans." (EN 50126-1:2017., p. 32) According to EN 50126-1:2017, humans may react differently in different situations, and to ensure the achievement of RAMS this will require more rigorous control of human factors than is required in many other industries.

Regarding the fact that it is mandatory by regulations to use the standard when renewals are planned and that RAMS performance is influenced by sources of failures it becomes interesting how the EN 50126 standard, deals with human errors. This leads to the question:

Is the outline knowledge about human factors used in subclause 5.6.4 Human factors in the RAMS standard (EN 50126-1:2017) enough to understand human errors?

The aim of this thesis is to illuminate in what way human error is explicated by the EN 50126.

Methodology

As Crotty (2015) states, our choice and particular use of methodology and methods reaches into the assumptions about reality we bring to our work (p.2). What epistemology is the underlying philosophy that guides what kind of knowledge would be possible to gain, and how can I ensure it to be adequate and legitimate becomes a pivot question. According to Crotty (2015) there are quite a range of epistemologies.

In an objectivist perspective, meaning that objects exist apart from any consciousness, objects, or meaningful reality, is out there waiting to be discovered. The aim is then to discover the truth, which implies there is a truth to discover.

There is a tantalizing notion about this, looking into formal documents like public assessments and laws and regulations it would be easy to consider those as a description of the truth. The same applies to documents and history-books, and I as the researcher could be able to discover their meaning, or meanings, which could be measured, sized, shaped, and counted in an objective manner.

Personally, I find it difficult to fully believe it would be possible to find a truly objective version of the truth. Public assessments, rules and regulations are a result of a social process. Even if some of those documents does describe differences in opinions or concerns, which could imply that they describe a truly truth. Such descriptions mainly reflect the social process during writing the document, it is still necessary to interpret them in the light of the time era they are written.

On the other hand, according to constructionism, there is not one objective truth that can be discovered, because reality is constructed. Knowledge, a meaningful reality is probably contingent upon human practices, constructed, and developed within a social context. "Constructionism claims is that meanings are constructed by human beings as they engage with the world they are interpreting. Before there were consciousnesses on earth capable of interpreting the world, the world held no meaning at all" (Crotty, 2015, p. 43).

The description of objects cannot be done in isolation without the experience from a conscious being, neither can experiences be described in absence of its objects. Reality, in the sense of how we make sense of it, depends upon our previous knowledge and focus, as Crotty describes the Stanley Fish experiment with the list of poets to different group of students (Crotty, 2015, pp. 45-46). The two group of students interpreted the list of names to have different meaning. Hence the meaning of the list is not apparent. What constitutes as meaning is an ongoing interpretation, set in motion by our interpretive strategies. There is no accurate interpretation, there are only interpretations which can be labelled useful, liberating, fulfilling etc.

Objectivism and constructionism are by no means the only variants of epistemology that can govern a research project. To me, they represent opposite sides of the basic epistemology, and I find myself disagreeing and agreeing with both. The epistemology that we choose as our underlying philosophy, affects the knowledge we are able to acquire. The choices and the way we apply the specific methodology and methods are influenced by our view of reality. The implication this has for my research is that I have to be critical of my interpretation of the documents. How I interpret the origin and meaning of the documents is a pivotal question. I believe that even public documents, such as standards that apparently express a truthfully reality; that truth is not a fixed property. It is the result of interaction between people with different conscious or unconscious epistemological approaches.

Method

At first, my intention was to study the standard and interview project managers, designers, and safety professionals about how they understand and use the knowledge on the subject of human factors provided by the standard. As I tried to reach out for interviewees this proved it turned out to be difficult. People where either too busy, did not want to participate, not responding or gave incomprehensible responses. This led me to alter my initial idea, from interviewing towards document analysis.

Document analysis is a systematic review and evaluation of documents. The purpose is to examine themes relevant to a phenomenon which is interpreted to gain an understanding and develop empirical knowledge.

Analysing a document involves reading the content, examining the document, and interpreting the text. A document analysis should include the origin of the document, when, where, what it is purpose, what changes has been made, why and which impact has the changes had, if any.

Document analysis is used to give data context, track development and to verify findings or confirm evidence from other sources. The analysis is an iterative process that involves assessment and reassessment of the data in documents.

Document analysis has its strengths and weaknesses. Some of the strengths are that document analysis is an effective method where data is selected rather than collected. Historical documents cover a long period of time. Documents are often easily accessible, and they are not affected by the researcher's presence.

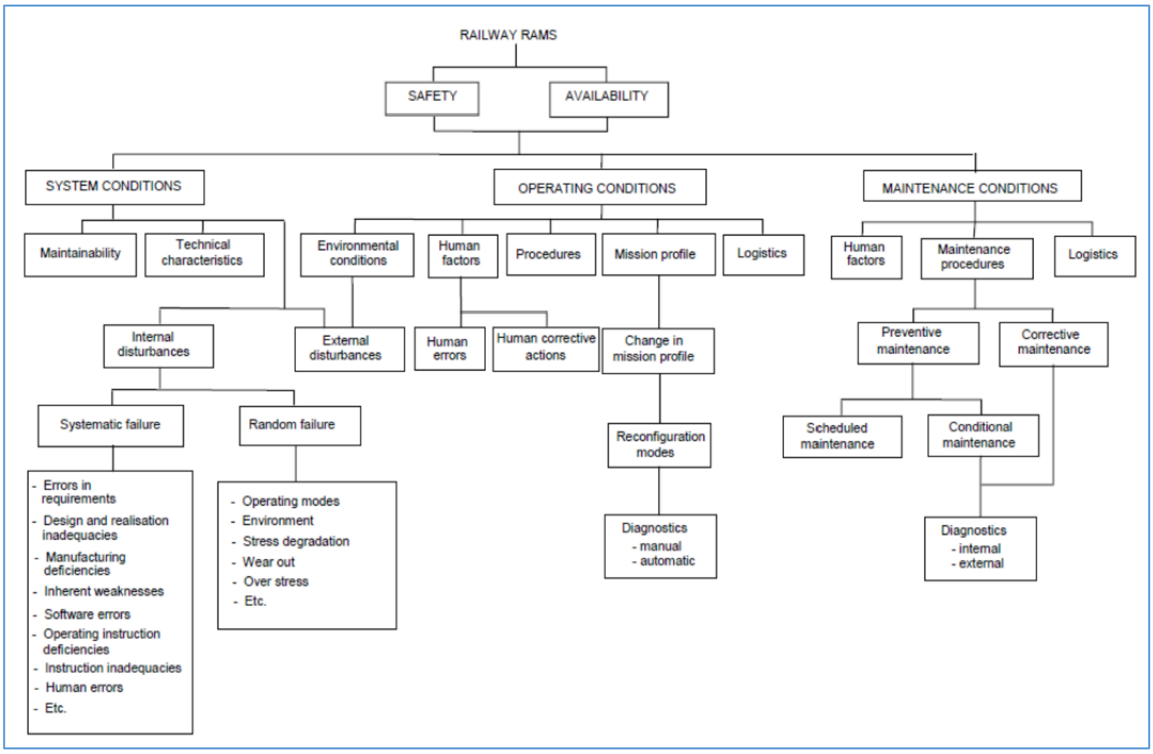
Some of the weaknesses are that documents may be insufficient; they are produced for purposes other than research. Documents may have low retrievability, which can occur if they are difficult to find or they may be blocked for various reasons. Document analysis is also subject to biased selectivity, which is to say that the available documents are often just parts of the document collection. (Bowden, 2009).

The document to be analysed is the EN 50126:1999 and the second edition EN 50126-1:2017. In the standard (EN 50126-1:2017), RAMS is characterised as a qualitative and quantitative indicator of the extent to which the system can be expected to function as specified and be both accessible and safe throughout the system's lifetime. System RAMS in this context is a combination of interrelated properties, reliability, availability, maintainability, and safety. Which is achieved by using established engineering concepts, methods, tools, and techniques (EN 50126-1:2017).

An important part of this is the derivation of factors that can affect the system. The detailed influencing factors that affect the RAMS of a specific system must be derived through a methodical process that considers each of the generic influencing factors within the context of the specific system.

Figure 1:

Generic factors influencing RAMS of the system EN 50126-1:2017 p.29.



Through my work as a safety advisor within the railway industry I first encountered the first edition of the standard in 2010. Some years after I had left the railway industry and during the spring of 2022 I changed workplace, and I was to return to the railway industry. By then a second edition of the standard had been issued in 2017, and I were curious about what changes had been made, especially with regards to human factors. In this thesis, the subclause *5.6.4 Human factors* in the EN 50126-1:2017 is the starting point of my document analysis.

For derivation of human influencing factors, the EN 50126-1:2017 provides a list of human factors that can be considered. The checklist consists of six areas, where point B-F is supported by further keywords or statements, which will be returned to later in this thesis. The main areas are:

A) the allocation of system functions between human and machine.

B) The effect on human performance within the system of

C) requirements on the system arising from

D) the requirements for the system arising from human information processing capabilities, including

E) the effect on the system of human/system interface factors, including

F) human factors in all phases of the system lifecycle, including

Taking the content of the suggested checklist in the standard as a lens, I explore how the topic human error is expressed by the standard, while linking it to some of the scientific literature about human errors. Further, I explore what kind of standard it is, and in which context it is situated. As I already have mentioned, in Norway the use of the standard is embedded into the Norwegian regulations. The standard provides objectives, requirements, and deliverables for RAMS activities to be undertaken throughout each life cycle phase. Analysis of those is outside the scope of this thesis.

My document analysis includes analysing the content of various types of documents, with a deeper analysis of both of the editions of the EN 50126 with a special focus upon the checklist related to human influencing factors provided in the standard. An overview of types of documents and data analysed is shown inTable 1, Types of documents and data analysed.

Table 1:

Types of documents and data analysed.

Types of documents	***Data analysed***
Railway history: books, notes, early regulations, internet pages. All publicly available	The development of railway technology, safety regulations, rail management
Public assessments. All publicly available through the Norwegian Parliament or Government webpages. Prints are available upon request, free of charges and shipping cost	Public assessments provides insight into societal focus areas and political directions. Public assessments includes accident analysis reports
Parliament and government assessments and decisions. All publicly available through the Norwegian Parliament or Government webpages. Prints are available upon request, free of charges and shipping cost	Laws and regulations made by the Norwegian parliament. Decisions made by the Government regarding transportation and organising the Norwegian railway sector
EU Directives, and regulations. All publicly available through the webpages EUR-LEX , an official website of the European Union	European decisions and development of regulations regarding the railway industry
Scientific articles and books	Scientific developments of safety, human factor, human error, standards, and standardisation
EN 50126-1:2017 Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) Part 1: Generic RAMS Process	Analysing how the topic human error is expressed by the standard.
EN 50126:1999 Railway applications – The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS).	Provides information of changes within the standard

The goal of this analysis is to derive in what way human errors is seen through the checklist for derivation of human influencing factors in the EN 50126-1:2017.

Literature review

The aim of EN 50126 is to provide railway duty holders and suppliers with a process that enables implementation of a consistent approach to the management of reliability, availability, maintainability, and safety (RAMS). An expressed assumption is that the achievement of a dependable system rest upon the ability to avoid weakness in the RAMS elements. According to the standard, mismanagement of conflicts between RAMS requirements can prevent achievement of a dependable system. An underlying assumption is that standardisation of processes reduces variation in the achievement of requirements, which in this context are requirements for the RAMS performance.

According to the EN 50126 technical concepts of availability are based upon the knowledge of reliability, theoretical maintainability, operation, and the actual maintenance work in terms of failure modes, frequency of occurrence, consequences of failure, time to detect and identify faults, time for restoration, in all operation modes, including human factor issues.

Failures in a system will, according to EN 50126, affect the system's performance. The performance of the system is determined through the systems design and defined functionality.

The literature review aims to look at safety research within subjects related to standards and standardisation, design, human factors, and human error.

Standards and standardisation

Organising and structuring the railway operations by instructions, rules and regulations is deeply embedded into the Norwegian and European railway system. The first Railway Act of 1848 required special instructions to prevent mishaps and accidents to happen as a result of dangerous railway operations. Local instructions were made for the employees at the Hovedbanen, and the instructions had a total of 153 points, which contained general personnel regulations and special safety regulations. Later such regulations were developed at a National level.

In 1975 the European Council issued a decision on the improvement of the situation of railway undertakings and the harmonization of rules governing financial relations between such undertakings and States. The goal was to eliminate differences that could lead to distortion of competition within the transport sector. This decision was further advanced by the Council Directive 91/440/EEC on the development of the Community's railways, which aimed to enhance the interoperability across the borders of the European Member states. The directive expresses an expectation for Member states to implement necessary measures for the development of their national railway infrastructure with regard to the community's needs. This includes establishing safety standards and rules and monitoring their application.

The establishment of a joint European railway network created a need for equal understanding of risks and compatible risk management. As Olsen (2020) points out, cross-border and institutional cooperation support the need for standardisation and with that, development of standards. The way we think about and manage risks are impacted by the production of standards.

Juhl (2020) highlights the fact that there are many players in the field of developing standards and defining risks. Each player with its own approach to what the terms risks, standardisation, and standard means, and none of the terms are autonomous, as they require humans to define their content.

According to Juhl (2020) sufficiently communication across native language barriers rests on a lingua franca. In linguistics this term is used for any language used for communication between people who do not understand each other's native language. The terms "standardisation", and "standard" are loanwords from various Indo-European language subfamilies and adopted in practically all European languages.

The word "standard" has its origins in Latin *norma*, and in the modern language the noun standard is used for a guideline, a rule, a set of rules or a norm. Setting a standard thus becomes the same as establishing a regulation. Standards would then be perceived as the best way to relate to something of importance. Standard could also be perceived as normal or usual, in the sense of mediocracy , a standard car is not an exceptional fancy car, but it is not a low-quality car either. From this it is possible to question if standards that regulate management of safety inspire mediocracy or excellence.

Standardisation is a verbal noun with three semantic meanings, and for all meanings, standardisation is always performed by humans:

1. Setting a standard for something.
2. Evaluating something by comparing it to a set standard.
3. Making something comply with an already set standard. Juhl (2020)

In principle, anyone can engage in the development of a standard. The work is usually done by members of different committees. The committees consist of representatives from organizations that will be affected by a standard. (NEK, 2023)

According to Hayes (2022) the standard must obtain sufficient credibility, input and output legitimacy is important. Input legitimacy is gained through the process of preparing and revising the standard. The output legitimacy depends upon its usability, which in the context of safety means it must be perceived by users as effective in preventing accidents.

Any given standard is the result of a multi-stakeholder process, and the content is sometimes subject to many rounds of reviews and formal voting. This opens up for the possibility of insiders manipulating procedural rules and players lobbying for their (economic) interests. Standard development organisations can therefore become very influential organisations where the socio-technical orders are negotiated (Hayes, 2022, p.2).

The RAMS-standard is a European standard developed and maintained by the European Standards Bodies CENELEC and the national CEN, which in Norway is the Norwegian Electrotechnical Committee (NEK) (NEK, 2023). NEK is a Norwegian supplier of regulations and standards for the electrotechnical area, together with Standard Norway and the National Communications Authority (Nasjonal Kommunikasjonsmyndighet Nkom), constitutes as one of the standardisation bodies in Norway.

Anyone can join the standardisation committees at NEK. Participants are expected to have sufficient specialist knowledge and the ability to set aside enough time to contribute to the work.

The Norwegian electrotechnical standards are generally based on the standards developed by International Electrotechnical Commission (IEC) and CENELEC. It is only as a member of NEK's committees that Norwegian representative, including regulatory authorities, can participate in international standardisation work (NEK, 2022). In the case where the international standards do not cover Norwegian needs, NEK then develop a specifically Norwegian standard to satisfy the Norwegian requirements. (NEK, 2023)

Anyone can make a proposal for standards; but it is usually generated by members of the standardisation bodies. The work would be assigned to a Technical Committee, and once the committee is established, the national committees decide their participation. In addition to members, technical committees include observers such as ISO/IEC members, European Commission/EFTA, European partners, external European industry associations and other affiliate bodies (CENELEC, 2022).

When the proposal for a standard is approved, a draft for the standard is developed. This is based on consensus-building. When the draft is established, a public enquiry is issued, and based upon the feedback the draft is either published or additionally worked upon and subsequently submitted to formal vote.

Human factors

The International Ergonomics Association defines Human Factor and Ergonomics as:

> "The scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimise human well-being and overall system performance" (Miranda, 2019 p.74).

The idea is improving performance, which means optimise several goals such as efficiency, productivity, maintainability and human values as safety, security, comfort, acceptance, job satisfaction and joy, is a core aspect of human factors. (Miranda, 2019; Shorrock & Williams, 2017)

Early human factors assessments can be traced back to the development of knowledge in areas such as, working hours during military operations, muscle fatigue and movement, cardiology and photography. Through scientific and experimental approach to the study of work, management, and standardisation of planning, tools, and working methods the on applied psychological studies within working environments, human factors as a topic grew in the immediate period preceding the First World War. During The Second World War there was a lot of collaborative scientific work in a wide range of areas, such as, environmental conditions in factories anatomy, physiology, psychology, industrial medicine, working hours, rest pauses, design engineering, architecture, and illumination engineering to investigate and provide solutions to the problem of selecting and training personnel. Problems like anoxia and pilot blackout were solved by new equipment and often brought spin off effects like cockpit redesign (Waterson, 2017, p. 31-33).

A great deal of rail human factor research was carried out during the 1960s and 1970s by the British Rail Research Centre, but most of this is no longer available. Rail human factors research are, to an extent, the forgotten branch of transport ergonomics. Throughout the 1980s and 1990s, the interest in railways as a transport system decreased, and even though human factors research continued, the magnitude was small, at least compared to road traffic and aviation. This has changed since the mid- to late 1990s (Wilson & Norris, 2005).

The European Union Agency for Railways, ERA uses the same definition for human factors as the International Ergonomics Association. The directive 2016/798 on railway safety (commonly referred to as The Safety Directive) requires railway undertakings and infrastructure managers to integrate human and organisational factors into their safety management system.

To achieve integration of human and organisational factors it is necessary to understand the context in which people work. By focusing on how the work is actually done, it is possible to identify challenges related to goal conflicts that may arise due to diverging expectations, resource scarcity or limitations in technical and technological systems. Success of the human working within a system, is an outcome of how the materials which they work with are designed to accommodate their needs. One way to measure success is to observe how long or how many attempts it takes for people to complete a task. Direct observations like this are sufficient for simple tasks, but not in complex systems where the environment can rapidly change. This requires a change in the focus on managing outcomes to a focus upon interaction, that is, regardless of an outcome, the quality of behaviour and decisions should be assessed within the framework of the operating environment at that time. (ERA, 2024; O'Flanagan & Graham Seeley, 2017; Miranda, 2019)

Systems thinking

Systems are more than the sum of its parts, a system consist of elements, interconnections, and a functional purpose. Physical elements of a system are easy to recognise because they consist of visible or detectable things. But elements do not have to be physical things; they can consist of abstract elements. (Wright, 1993/2008).

Elements of a railway consists of visible things like the tracks, trains, power supply, but also abstract elements like safety rules, communication between different engineering disciplines within railway construction, or communication between traffic controllers and the maintenance crew. All of those elements can be further divided into specific part, like the track can be separated into switches, curves, climbs and so on. This can also be done for less physical elements, communication between traffic controller and the train driver can be described in terms of how to say what. The involved crew have to follow specific wordings before the track can be set in service after the maintenance is carried out.

Elements of a system is the stock of a system. Stocks changes over time by actions of flow, and stock can be increased by decreasing its outflow as well as increasing its inflow. How fast the stock changes depends upon how long the flow takes.

Interconnection relates to the flow and reactions. Feedback-loops are the signals that allow one part to react to another part. Feedback loops emerges when a change in a stock affects the flow, if there is an increase in the inflow the stock will grow, this can also be achieved by decreasing the outflow. Feedback loops works both ways (Wright, 1993/2008).

Some interactions are easier to see, like the train traffic starts up again after the maintenance has been conducted. Other interactions can be harder to see, like effects of periodical revision of procedures. If we consider the railway system stock to consist of infrastructure, trains and passengers, sudden changes in number of available trains creates an increase in waiting passengers, but it does not change the system of transportation. The same can be said for numbers of passengers and infrastructure. Temporary changes in the stock, may not change the system. As we saw by the lock-down during the Corona pandemic. In Norway, the government swiftly locked down the society and many employers had to work from home, this created a sudden and sharp decrease in numbers of train passengers. This did not change the railway as a transportation system, soon after the reopening of the society the numbers of passengers are approximately the same as before.

Feedback loops can be balancing loops or runaway loops. Balancing loops would work to stabilising the stocks, as the example of changes in passengers due to the pandemic. Such balancing loops works in every direction, if some elements are decreased other element would increase, the goal is to obtain balance or stability.

Runaway loops are feedback loops that is amplifying and reinforcing, it generates more input to a stock the more that is already there and less input that is already there. Reinforcing feedback loops are self-enhancing and will eventually lead to runaway collapses over time (Wright, 1993/2008, p. 15-33).

If the railway transportation system gains more passengers than it can handle, people will eventually find other means of transportation, which will affect the balancing feedback loops within the transportations system.

There can be multiple feedback loops within a system, they can work against each other or try to come into balance of each other. As a result, complex systems does more than smoothly approach goals and grow neatly.

The purpose of a system is not necessarily stated, written, or expressed explicitly. A good way to derive the system's purpose is to study the system over time to see how it behaves. System purposes are not necessarily those intended by any single actor within the system. System can be nested in systems, which means that there can be elements in elements, interconnections within interconnections and system purposes within system purposes (Wright, 1993/2008, p. 15-33).

To treat a piece of equipment or a workplace development as if it were an isolated island, separated from the rest of the world would not be effective. Train operators and infrastructure entities must account for the inter-operability of their operations with other modes of transport or railway in other countries. Interactions takes place and vary through the whole lifecycle, from development, operational, maintenance, and decommissioning (Wright, 1993/2008; Wilson, 2013).

According to Wilson (2013) it is not unusual that different professions have diverse perception of what constitute as a system boundary. There are no clear rules for how to describe and define a system, apart from the fact that the boundaries for what belongs to the system of interest must be sensible enough for analysis. A comprehensive system must combine the cognitive, physical, and social to a degree appropriate to the issues to be studied or improved, and the type of investigation, analysis and solutions involved. Modelling the system can be useful, but a model will always fell short of reality, at least when it comes to ways socio-technical systems can interact.

All systems in real use, will at some point operate in unexpected or unplanned ways. One familiar example is dismantling safety-shields of the edge cutter, another way could be when people make workarounds, like taping sustention cords to electrical tools when the cord is short, to make systems work despite its shortcomings. Yet another way, is when people take advantage of a products property in a way that was not intended, like when a child plays with the box of the toy, rather than the toy itself (Wilson, 2013, p.7-9).

Design

Norman (2013) states that "Design is concerned with how things work, how they are controlled, and the nature of the interaction between people and technology" (p.5). Design has an impact on goal achievement and done well it contributes towards goal realisation; done badly it can create great confusion and frustration.

According to Norman (2013) when people use something, they face two challenges. The challenge of execution, how to operate it, and the challenge of evaluation, what happened. For design, the aim is to narrow the gap between achievement of the goal and the challenges of execution and evaluation. If the gap is small and the goal was met easily everything is fine. But, if the goal was not met, people will evaluate what happened. (p.41).

Figure 2:

The Gulf of Execution (Norman, 2013, p. 41).

FIGURE 2.1. The Gulfs of Execution and Evaluation. When people encounter a device, they face two gulfs: the Gulf of Execution, where they try to figure out how to use it, and the Gulf of Evaluation, where they try to figure out what state it is in and whether their actions got them to their goal.

In order to bring us towards our goal, Norman (2013) points to the seven stages of action, which includes the forming of the goal, the execution, and the evaluation. The execution consists of planning the action, specify the action sequence and perform the action. The evaluation part is made up of, perceive, interpret, and compare, did we make it towards our goal, why or why not.

The insight from those stages leads according to Norman to seven fundamental principles of design. Discoverability, feedback, conceptual model, affordance, signifiers, mappings and constrains are the seven principles which involve assessment of whether it is possible to understand the conceptual model in the design, the state of the product or service, which actions can be performed, how feedback after an action can be identified, as well as whether the design provides physical, logical, semantic and cultural constraints guides actions and facilitates interpretation.

The author argues that by applying the fundamental principles of design, taking a human-at-centre point of view, how things are designed, can either contribute or inhibit how people behave while interacting with things or within systems.

Human error

Read et al. (2021) explores the early history development of the term error. Error derives from the Latin "errorem", which meant a wandering, straying, a going astray; meandering; doubt, uncertainty; also, a figurative going astray, mistake. Around the 13th century, the middle English error meant, among other things deviation from truth, wisdom, good judgement, sound practice or accuracy made through ignorance or inadvertence; something unwise, incorrect, or mistaken or an "offense against morality or justice; transgression, wrong-doing, sin" (Kurath 1953/1989, cited in Read et.al., 2021)

Human error is a long-time standing topic of science. According to Le Coze (2022), the topic origins "from disciplines such as cognitive psychology, engineering and system thinking, based on a mix of experimental and empirical data from various industries". (p.1).

Based upon Reason's early work on error, Freud's thoughts about mental control structure and model of schema activation, Norman (1981) set up a framework for categorisation of action slips. The model, an Activation-Trigger-Schema system (ATS), assumes that action sequences are controlled by sensorimotor knowledge structures, schemas. The model is based on activation and selection of schemas using triggering mechanism that requires that appropriate conditions be satisfied for the operation of a schema. Each activated component is a sensorimotor schema, with conditions that specify when it is to be triggered into action. Several schemas are activated at any given time, and the determination of the correct triggering conditions for a given schema is a critical factor for the correct execution of an action. Specifications of intention has to be decomposed until essential level of act specification is reached. Monitoring of actions are a basic component of a feedback control system. Feedback and monitoring is required at each level.

The model allows for multiple sources of activations, such as the external world, what the author calls data-driven activation, from internal processing, that is thoughts, and associations, prior or future action components, or by capture by well-learned familiar habits (Norman, 1981, p. 14).

Rasmussen (1971) points to the very reason for having a human element in the system is its ability to tailor decisions and actions if favour of the system. (p. 150). The human ability to be a part of a control system depends upon information about the state of the system, the purpose of the system and possibilities to take actions. Especially when the system behaves in an unexpected way.

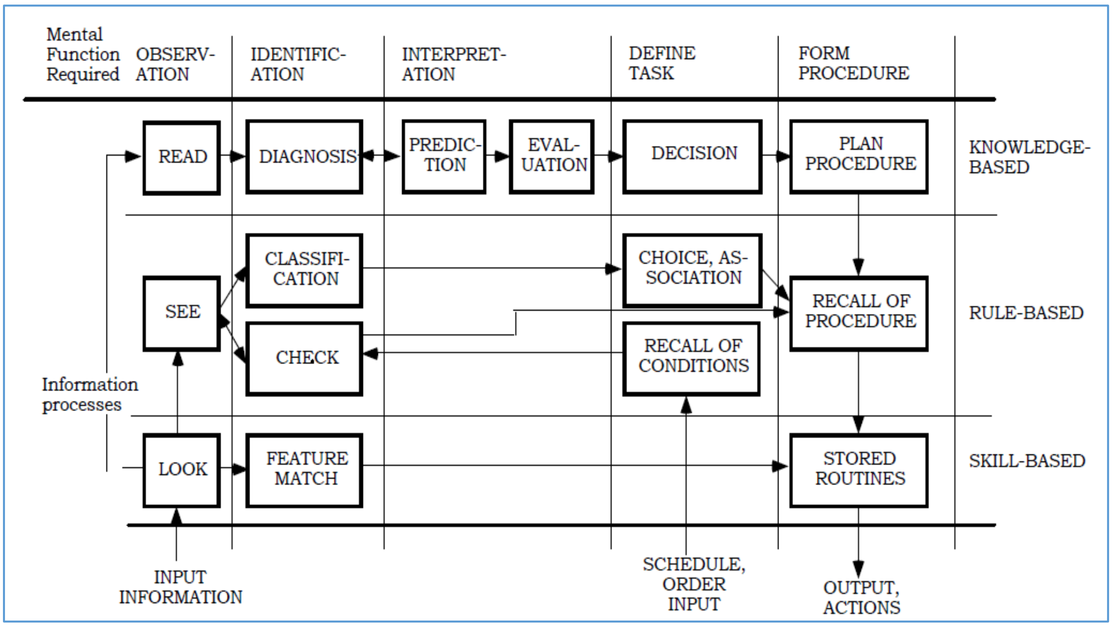
In a later paper, Rasmussen (1982) suggests that analytical efforts to include human errors are based on “a model of the task rather than a model of the man performing the task” (p. 2). This in turn has according to Rasmussen (1982) led to a definition of error and error quantification rates through external concepts related to the task, and to a lesser extent to human functions, abilities, and limitations.

According to Rasmussen (1982) analytical assessments of probabilities and consequences of an accidental chain of events rest upon the knowledge of failure modes of the system components. A basic assumption is that the mode of components is represented by an input-output model where transferees into a failure mode is known. This idea is then transferred to the human system component. The researcher argues that such a model is unrealistic as it does not consider selective filtering of error mechanisms depending upon reversibility features of the task context. (Rasmussen, 1982, p. 4). Neither does it consider human intention and expectations. This suggests that there is not a passive one-to-one relationship between the actual execution of tasks and the intentions and expectations. In real life, people actively seek information to solve the goals of the tasks: “Trained people ask questions to the system, biased by their experience and immediate expectations; they do not passively receive and filter an information input” (Rasmussen, 1982, p. 4-5).

Error mechanism cannot be directly observed, and in order to interpret such mechanisms and Rasmussen (1982) presents a model of human information processing. This model draws a distinction between three levels of behaviour, skill-, rule-, and knowledge-based performance, based upon error judgement and concepts for controlling behaviour.

Figure 3:

Diagram of mental functions by different information processes - each with particular error mechanisms (Rasmussen, 1982, p. 7).



In any skill-based area, errors are related to variation in force, space, and time coordination. Performance is guided by stored behavioural patterns within a time-space domain.

For the rule-based domain, errors are usually linked to mechanisms such as errors in recognition and categorization of the situation, incorrect associations, or lack of recall of procedures. The rule-based domain includes performance in familiar situations controlled by stored rules for coordinating underlying routines, and since rule-based behaviour is used to control skill, rule-based behaviour will also involve the presence of mechanisms to control skill-based errors. This means that transferring knowledge about controlling and error recovery to new tasks is difficult. The new tasks must be sufficiently similar to the old tasks for a continuation of the control mechanisms to have value.

The knowledge-based domain is related to unfamiliar situations, where actions need to be planned based upon insight of the functional physical properties of the system, as well as goal priorities. Error mechanisms linked to this area must be defined in relation to the goal of the task. Generic error mechanisms can only be derived through detailed descriptions of the data process itself. In such situations, error mechanism are linked to applying the right behaviour for an abnormal situation. Such error mechanisms are linked to the consequences of information cannot be derived from deficiencies in information to a passive recipient of information.

An important factor that Rasmussen (1982) points out is that it is very difficult to give a clear definition of human error. Such errors are often defined after an event based upon whether the system has functioned as expected. If it is assumed that a human action, or inaction, could change the outcome, the cause of the change is judged as human error.

Amalberti (2013) structures different types of errors inspired by Rasmussen's model of Skill-based, Rule-based and Knowledge-based behaviour where the author evaluates frequencies and recovery of human errors. The most frequent errors are routine errors, this is errors in monitoring work as done. Actions are carried out without conscious control, in the context of a familiar type of work. This correlates to Rasmussen's (1982) skill-based errors.

Errors of rule activation are errors that emerge by choosing the wrong solution. The person is aware of the presence of a problem and has the requisite knowledge but are not able to recover the error. A subcategory of errors of rule activation is errors of representation. In this case the operator applies the procedure correctly, but the procedure is not relevant in the specific context. Fixation errors are a subset of both errors of rule activation and errors of representation. This type of error relates more to teams than to a single person. Errors of rule activation and its subcategories are less frequent and correlates to Rasmussen's (1982) rule-based behaviour.

Errors due to lack of knowledge are errors that occurs when the operator does not know the solution to the problem. The person has to mobilise all his/her the cognitive ability to slowly step-by-step come up with a new solution. The error can take another form when the right solution appears too late. These errors are rare among professionals but can be more severe in terms of safety consequences. This type of errors correlates to Rasmussen's (1982) knowledge-based behaviour.

According to Amalberti (2013) the frequency of errors does not predict the persons behaviour, it is the detection and recovery strategies that is the best predictor of performance.

Mitigate errors.

Amalberti (2013) points out that human performance is not related to the number of errors, but discovery and recovery from errors. Discovery of errors helps people use the results as a further basis for understanding problems and recover from errors.

The researcher suggests four main strategies to detect and recover errors. The strategy that detects the largest numbers of error by volume is direct-error-hypothesis formation, which are discovered continuously without special attention. The result is considered bizarre and a hypothesis about what is wrong is immediately formed. The routine control processes for detecting errors are an essential part of performance among experts. However, routine errors are not detected particularly more often among experts than among less experienced personnel.

As the tasks become more complex, the complexity of errors increases, and the detection of less frequent errors increases. The detection and recover strategi for errors of rule activation and its subcategories are error-suspicion. In situations where this strategy are used are when part of the result is considered to be bizarre, but it is not possible to immediately figure out what is wrong.

Affirmative evaluation is used as a detection and recover strategy when checks is carried out independently of any specific suspicion and discovers of errors.

Each of the steps of detection and recovery creates the opportunities for different errors, which in turn is detected and recovered based upon a system in dynamic equilibrium, where error generation rate is linked to detection and recovery rate.

The challenge, as Amalberti (2013) sees it, is that when the tasks become more complex, there are more and more areas that are not understood, and more and more routines are often established. The paradox then is that the person who has to solve the tasks can make several routine errors that are not detected due to increased attention to activities related to understanding.

In situations that require more concentration, the number of errors decreases and most of these are detected and corrected. The paradox is that when the person in question loses control in extreme situations, it is not because of the number of mistakes. Loss of control occurs as a result of an imbalance between sufficient resources to recover from the few errors that are still made (Amalberti, 2013).

Reason (1997) states that "the term human error conveys the impression that all unsafe acts can be lumped into a single category" (p.61). People's behaviour is far more constricted in a hazardous system than in everyday life, different errors have different psychological origin, and require different strategies. People's behaviour in high hazard systems is tightly governed by internal and external controls. External controls are made up of regulations, rules and procedures, internal controls are acquired from the knowledge and principles through training and experience.

Based upon Rasmussens model of human information processing, Skill-, Rule- and Knowledge-based behaviour, Reason (1997) sets up error types related to the intention of the goal and the means to achieve it. This involve three elements. First, there must be a plan or intention that includes the goal itself and the means to achieve the goal. Secondly, it is assumed that the plan triggers a sequence of actions, and finally this also implies the extent to which the actions are successful with regard to goal achievement.

According to Reason (1997) actions may fail to achieve goals because they did not go as planned. Reason (1997) terms this as skill-based slips, lapses and stumbles, which origins in attentional slips of actions and lapses of memory.

Achievement of goals can failure if the plan is insufficient. In such cases, the failure is related to mental processes involved in evaluating available information, formulating intentions, and expectations of the outcomes of actions. This type of error is defined by Reason (1997) as mistakes and has two subcategories, rule-based and knowledge-based mistakes. Rule-based mistakes are related to incorrect application of rules, bad rules, or failure to apply rules. Knowledge-based mistakes occur when previous experience cannot be used as a basis for problem solutions and new solutions must be established.

Error management would consist of error containment and reduction. This are often event-driven, and fragmented . Error containment consist of measurements to increase error detection and the organisations error tolerance in addition to minimise error liability of the individual or team. Error reductions relates to measures to discover, assess, and eliminate error producing factors within the workplace.

Human error in this context is the result of workplace factors and organisational conditions. Identifying human error is the beginning of the search for causes, and only by understanding the context that led to the error is it possible to limit its recurrence. (Reason, 1997)

Findings from the Document Study: The EN 50126 Documents

The EN 50126 Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) is a standard aimed at a common way to manage the RAMS of a railway system. The first edition was issued in 1999 and in 2017 a second edition was issued, where the standard are divided into two parts. The Generic RAMS Process is part 1 and part 2 focuses on the Systems Approach to Safety

This section describes the landscape where the EN 50126 is situated and some of the changes between the two editions.

The document landscape.

As part of safeguarding technical quality for products marketed in the common European market, the EU implemented a system for product certification. This system is based, among other things, on harmonised technical standards which sets requirements of the product's safety, such as mechanical resistance and stability, generation and spread of fire and smoke, avoidance of electric shock, etc.

Approval of the fulfilment of requirements is documented through either the EC-Conformity Mark, EC-Conformity Certificate or EC-Declaration of Conformity issued by a standardisation body, certification body or inspection body on the basis of test results and/or documented quality in production processes (Dir 83/189/EEC; Dir 89/391/EEC).

Harmonised standards.

According to CEN, the Committee for Standardization standards (CEN) are technical documents which are used as definitions, rules, or guidance. The benefits of standards are that they contribute to consistent product quality and safety and lowering transaction costs. Standards are built upon consensus between interested parties, such as manufacturers, consumers, and regulators. Standards should be based upon the overall result of science, technology, and professional experience.

Standardisation is a valuable tool for strengthening competitiveness of businesses. Standards provides the opportunity for various products that are used can be connected and function in a safe way (CENELEC, 2022).

In principle, the use of standards is voluntary, but around 30% of the European standards published by CEN and CENELEC have been developed at the request of the European Commission. Such standards are so-called harmonised standards (CENELEC, 2022). This means that the standard helps to ensure compliance with requirements in EU directives. Use of those kinds of standard provides a presumption of compliance with requirements in relevant legislations (CENELEC, 2022).

The EN 50126 is a harmonised standard, and thus implies compliance of legislative requirements.

Norwegian rail regulation

At the time the first edition of the EN 50126:1999 was published there were no requirements in the Norwegian railway regulations that the standard should be used. The specific requirement appeared much later, in 2011.

Rail technical requirements have been part of the Norwegian regulations from the very beginning. In the first Railway Act issued in 1948, this was laid down in §1, where it was established that railways must be designed and built to ensure safe and appropriate traffic operation. This requirement was continued in the current Railway Act from 1993. While the requirement for concession would be satisfactorily handled through the Expropriation Act and the Planning and Building, further specifications were mainly targeting the railway entity's ability to manage the railway system. This should be supervised and approved by an authorised entity.

Through the 1990s, the organisation of the Norwegian railway industry was changed, and with that the regulations also changed. Requirements for authorisation to manage and operate railway infrastructure were in Norway laid down in FOR-1999-12-23-1402 Regulations on requirements for management and follow-up of conditions relevant for safe traffic management on railways, including tramways, subways, and suburban railways, etc.

In 2000, one of the worst railway accidents in Norway in recent times occurred. Two diesel-powered passenger trains collided at Åsta between Rudstad and Rena. Nineteen people died in the collision and the following fire. A few days after the accident, a royal commission of inquiry was set up to investigate the cause of the accident and propose measures to avoid similar accidents. The commission could not with certainty determine the cause of the accident. The commission also focused upon underlying causes and attracted a lot of public attention due to strong criticism of towards the insufficient safety management system of the Rail Infrastructure Manager (JBV) (NOU 2000:30).

In the aftermath there was almost an explosion in the number of regulations that were frequently revised. Requirements that had been addressed in FOR-1999-12-23-1402 were now divided into separate regulations regarding specific areas. The first regulations regarding requirements for a safety management system as a necessary condition to obtain authorisation to manage and operate railway infrastructure came into force in 2001. This included technical requirements and permission to set sub-systems of control and signals, energy, and infrastructure into service.

During the 1990's Europe took actions for the development of the Community's railways and Council Directive 91/440/EEC were issued to facilitate the adoption of the Community railways to the needs of the Single Market and to increase their efficiency. European requirements for technical specifications of interoperability (TSI) first appears whit the development of interoperability of the trans-European high-speed rails system (Dir 96/48/EC) which sets requirements regarding reliability, availability, safety for the railway system. An important part was to make sure that those technical requirements were compiled by and certificated by a notified body.

To support the industry with its obligations to comply with those requirement, normative standards was developed or stated, the EN 50126:1999 was one of those standards. Furter development of the Community`s railway included technical requirements of interoperability of conventional rail system, and Directive 2001/16/ was issued.

As Norway has a strong connection towards Europe, through the EEA agreement Norwegian regulations are developed with regards to EU agreements. In 2003 FOR-2003-02-05-137 Regulation on interoperability in the trans-European conventional rail system (interoperability regulation) the requirements regarding technical specification's would apply for the Norwegian rail system.

In order to put the subsystem into service there must be permission to use the subsystem, this in Norway regulated by the FOR-2021-09-09-2742 Regulation on the interoperability of the railway system.

The sub-systems Control, control and signals along the track, Energy and Infrastructure can only be used if they are designed and built in a way that they meet the relevant basic requirements.

Before a subsystem is renewed or upgraded, the applicant must send a notification to the Norwegian Railway Authority with documentation describing the project. The Norwegian Railway Authority shall, based upon the information decide if it necessary to apply for permission.

If it is necessary to apply for a new permission, the application should include EC verification statement, documentation of the subsystems' technical compatibility with the system in which they are integrated and documentation of safe integration of subsystems, based upon relevant TSIs, national rules as the FOR-2011-04-11-388 Railway Infrastructure Regulations and common safety methods as described in (EU) No 402/2013.

The requirement to use of EN 50126 is situated in the Norwegian FOR-2011-04-11-388 Railway Infrastructure Regulations. The requirements in Railway Infrastructure Regulations addresses general technical requirements for the railway system, which are not in themselves subject to permits or authorisations. The first edition of the Railway Infrastructure Regulations from 2011 refers to EN 50126:1999, while there is no specific reference of which edition of the EN 50126 that should be used in the current FOR-2011-04-11-388 Railway Infrastructure Regulations.

In order to set into service new or renewed infrastructure, the National Safety Authority (SJT) have to give a written statement of permission. This permission would be based upon information about the renewal or what changes has been done by renewal, in addition to information about safety. Permission to use the specific subsystem that are constructed or renewed is situated in FOR-2021-09-09-2742 Regulation on the interoperability of the railway system.

This means that the requirement to use the standard in Norway is contained in two regulations that regulate different areas. In my experience as an active RAMS-advisor this dual relationship can be experienced as confusing. Sometime this leads to that the work to establish the information required by the EN 50126 starts well into the projects progress, especial within smaller projects. The focus is upon getting permission to use the installations. I believe part of the explanation lies in the fact that technical requirements and with that fulfilment of requirements in TSIs are embedded into the railways own technical descriptions. These technical descriptions have always existed, and they are regularly updated in line with technological development and changes in technical regulations from both Europe and Norway. These internal technical requirements are highly respected within the railway and a lot of effort is put into ensuring that the design is in accordance with these requirements.

It can thus be perceived as meeting the requirements of EN 50126 lays outside the already established systems for compliance with technical requirements. This is not the case every time a renewal is embarked upon, but it often questioned if it is necessary to use all of the requirements in EN 50126. It is not, in many cases it is necessary to tailor the work required by the standard. Permission to set into service does not rest on the use of the standard, it rest upon the projects ability to manage safety and making sure that the design are compliant with relevant TSIs. Using the EN 50126 is one of different means to achieve this.

Body of Knowledge, Core Aspects Within the two editions of EN 50126

Both editions of the EN 50126 provide explanations on the subject of reliability, availability, maintainability, and safety (RAMS).

In this section, I will take a closer look at some of the explanations provided in the EN 50126 that have, and have not, changed between the two versions of the standard.

Railway RAMS

The intention of the baseline information on the subject of RAMS in the first edition of the standard, EN 50126:1999 is to "provide the reader with sufficient background information to enable the effective application of the standard to railway systems" (EN 50126:1999, p. 12). In the second edition of the standard, EN 50126-1:2017 the information is intended "to enable users of the standard to fully understand what is required to comply in an appropriate way with the provisions of the normative text throughout the standard." (EN 50126-1:2017, p. 20).

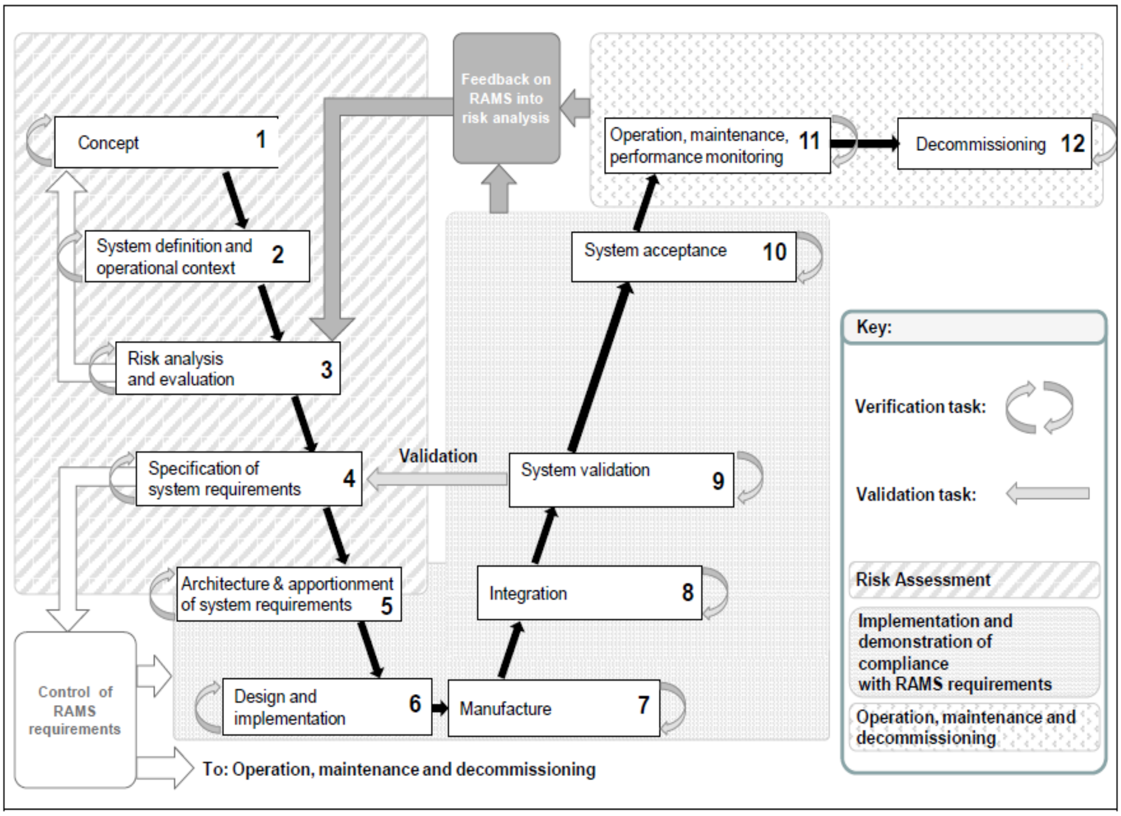
The change from a sufficient background for effective use of the standard, to a full understanding of what is necessary for proper compliance indicates that it is no longer sufficient to comply with the requirements of the standard. The requirements must be fully understood and complied with in an appropriate way. In the introduction of the second edition of the standard it is recognised a need to deliver a systematic and coherent approach to RAMS applicable to all the railway application fields Command, Control and Signalling (Signalling), Rolling Stock and Electric Power Supply for railways. This implies to me that there probably have been differences in the practical use of different standards across different engineering fields.

Management of RAMS The "V-model"

Both editions present the life cycle model as the basis for managing RAMS. The model provides a structure for planning, administration, control and monitoring of all aspects of a system. The lifecycle is presented by both editions as a sequence of phases, each containing objectives, tasks, and deliverables covering the total life cycle of a system from initial concept to decommissioning, presented by the "V-model".

Figure 4:

Representation of the "V-model" in EN 5016-1:2017 (p. 39).



While the focus in the “V-model” is upon validation and verification in the first edition, EN 50126:1999, the second edition also emphasises management of safety. The second edition provides specific requirements for safety activities in EN 50126-2:2017 *Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) Part 2: Systems Approach to Safety.*

This part 2 of the standard takes a perspective of safety with a functional approach. The standard introduce the Hourglass Model which provides an overview of safety-related activities that are needed to ensure an acceptable safety level for a technical system. While interfaces considering interactions with humans, and maintenance manuals and operation is described, humans are not considered to be a part of the technical system. They can, according to the part 2 of the standard be restricted by application conditions. The purpose is to highlight the difference between risk assessments with regards to the railway system, and hazard analysis as a part of hazard control. (EN 50126-2:20217, p. 9) This lifts human factors out of the equation and the focus becomes solely on technical aspect.

Organisational requirements

The second edition of the EN 50126-1:2017 has a separate clause addressing organisational requirements. The clause has two main focuses, one of which is that responsibility for RAMS tasks should be described and regulated in contracts when the roles are assigned to different stakeholders. The second focus is ensuring independence between those who carry out RAMS tasks and those who assess or validate. Verification and validation of the implementation and demonstration of compliance must also be described and regulated in contracts between actors.

Systems

While the description of systems are scarce in the first edition, the second edition provides an elaborated explanation. The first edition defines system as an assembly of sub-systems and components, connected together in an organised way, to achieve specified functionality. (EN 50126:1999, p 12). The second edition does not give a clear definition of a system but offers a way of thinking while defining a system. “A system comprises not only its technical components but also the interaction with the humans developing, operating, and maintaining it.” (EN 50126-1:2017, p.23). Further details are given in clause *7*

RAMS life cycle which describes objectives, requirements, and deliverables for RAMS activities to be undertaken throughout each life cycle phase.

The second edition introduces the notion that what can be considered as a system or sub-system depends on a person's point of view. What can be regarded as a system by the people who develop it, can be seen as a sub-system by the people that use it as a part of their system.

Both editions stress that functionality is assigned to subsystems and components and the behaviour and state of the system changes if the subsystems and components change, a system responds to inputs to achieve specified outputs. While the second edition offers more exploration towards systems, it does not give any explanation about what interactions rely upon. At least not in the sense of system thinking as provided by Wright (1993/2008), where systems are regarded as more than the sum of its parts, and interconnection relates to the system flow and reactions. Neither does it provide any information about feedback loops as balancing or runaway loops, the fact that there may residue more than one feedback loop and that such loops works in every direction. The standard does not take into consideration that as a result of multiple feedback loops complex systems does more than neatly approach goals. The view of systems consisting of components are the same in both editions.

Influencing factors

Both editions state that dependable systems rest upon, identifying factors which could influence the RAMS of the system, their effect assessed, and the cause of these effects managed throughout the life cycle of the system, by the application of appropriate controls to optimise system performance. The RAMS performance can according to both editions be influenced in three ways.

Those are described in the first editions as sources of failure within the system at any phase of the system lifecycle (system conditions), by sources of failure imposed on the system during operation (operating conditions) and by sources of failure imposed on the system during maintenance activities (maintenance conditions). (EN 50126:1999., p. 15).

The description in the second edition are almost identical:

- "by sources of failure introduced internally within the system at any phase of the system life cycle;
- by sources of failure imposed on the system during operation; and

- by sources of failure imposed on the system during maintenance activities" (EN 50126-1:2017, p. 27).

According to both editions these sources of failures can interact. None of the editions offers any explanation to what interaction means in this context.

Failure

The terms and definitions regarding errors, failure and faults provided in the two editions of the standard are shown in Table 2 Extract from clause 3 Terms and definitions related to failure. (EN 50126:1999 p. 8-12 & EN 50126-1:2017 p 9 -20)

Table 2:

Extract from clause 3 Terms and definitions related to failure. EN 50126:1999 p. 8-12 & EN 50126-1:2017 p 9 -20.

Terms and definitions	**EN 50126:1999**	**EN 50126-1:2017**
Error	-	Discrepancy between a computed, observed or measured value or condition and the true, specified or theoretically correct value or condition. Note 1 to entry: An error can be caused by a faulty item, e.g. a computing error made by faulty computer equipment. Note 2 to entry: *A human error can be seen as a human action or inaction that can produce an unintended result.(emphasis added)*
Failure cause	The circumstances during design, manufacturing or use which have led to a failure	-
Failure, <of an item>	-	Loss of ability to perform as required. Note 1 to entry: Qualifiers, such as catastrophic, critical, major, minor, marginal and insignificant, may be used to categorize failures according to the severity of consequences, the choice and definitions of severity criteria depending upon the field of application. Note 2 to entry: Qualifiers, such as misuse, mishandling and weakness, may be used to categorize failures according to the cause of failure. Note 3 to entry: "Failure" is an event, as distinguished from "fault", which is a state.
Failure mode	The predicted or observed result of a failure cause on a stated item in relation to the operating conditions at the time of the failure	Manner in which failure occurs
Failure rate	The limit, if this exists, of the ratio of the conditional probability that the instant of time, T, of a failure of a product falls within a given time interval (t, t + Δt) and the length of this interval, Δt, when Δt tends towards	Limit of the ratio of the conditional probability that the instant of time, T, of a failure of a product falls within a given time interval (t, t + Δt) and the duration of this interval, Δt, when Δt tends towards zero, given that the item is in an up state at the start of the time interval.

Terms and definitions	EN 50126:1999	EN 50126-1:2017
	zero, given that the item is in an up state at the start of the time interval	Note 1 to entry: For applications where distance travelled or number of cycles of operation is more relevant than time then the unit of time can be replaced by the unit of distance or cycles, as appropriate. Note 2 to entry: The term "failure rate" is often used in the sense of "mean failure rate" defined in IEV 192-05-07.
Random failure	-	Unpredictable failure which results from one or more of the possible degradation mechanisms
Fault, <in a system>	-	Abnormal condition that could lead to an error in a system. Note 1 to entry: A fault can be random or systematic.
Fault mode	One possible of the states a faulty product for a given required function	
Systematic failures	Failures due to errors in any safety lifecycle activity, within any phase, which cause it to fail under some particular combination of inputs or under some particular environmental condition	Failure that consistently occurs under particular conditions of handling, storage or use. Note 1 to entry: A systematic failure can be reproduced by deliberately applying the same conditions, although not all reproducible failures are systematic. Note 2 to entry: The cause of a systematic failure originates in the specification, design, manufacture, installation, operation, or maintenance of the item.

The first edition offers no more explanation regarding failure or error besides what is presented in clause *3 Terms and definitions*. The second edition provides a subclause *5.6.2 Classes of failures* where failures are divided into random failures and systematic failures.

In this subclause, it is stated that "random failures are due to causes which can be described by statistical distributions" (EN 50126-1:2017., p. 27) and they can be statistically monitored so that their probability of occurrence can be estimated.

Systematic failures emerge as a result of life cycle activities for which statistical data is not usually available so that their probability of occurrence cannot generally be estimated. Systematic failures can make the system to fail in a similar way under particular conditions, such as combination of inputs and triggering events for example non-fulfilment of application conditions (EN 50126-1:2017., p. 27).

Further it states that "Systematic failures are mainly caused by human errors in the various stages of the system life cycle. Therefore, systematic failures are mainly treated by the application of appropriate processes, methods, and organisation." (EN 50126-1:2017., p. 27).

Human influencing factors

At first glance, it seems like human factors has gained more attention in the second edition than the first, as human factors has its own subclause in the second edition. The reason for this is not obvious as the changes regards to human factors between the editions are minor.

The definition of human factors as "the impact of human characteristics, expectations, and behaviour upon a system. These factors include the anatomical, physiological, and psychological aspects of humans" (EN 50126:1999 p. 15 & EN 50126-1:2017 p 32) are exactly the same in both editions. This definition seems to be specific for the EN 50126, the focus is upon how human factors can impact a system. In the definition of human factors used by IEA and ERA the focus is upon understanding interactions among humans and other elements of a system.

Both editions state, in exactly the same wording, that the concepts of human factors is used to enable people to work efficiently, with due regard for human needs on issues such as health, safety, and job satisfaction. Which is consistent with the rationale for human factors as defined by the IEA, CIEHF; HFES.

Both editions recognise the fact that humans can impact a system both in a positive and negative way. However, this is described in slightly different ways. While the first edition states that the railway applications involve a wide range of human groups, the second edition separates this into different clauses and sections of the document. The second edition describes who the stakeholders involved in a railway system are and their role regarding the railway system. The first edition provides no such explanation.

Both editions state that humans can react differently in different situations, which requires more rigorous control of human factors through the lifecycle than is required in many other industrial applications. The second edition specifies that this includes all lifecycle phases, not only in Operation, Maintenance and Performance Monitoring phase.

The second edition adds an explanation regarding human performance and competence. According to EN 50126-1:2017

> "All humans experience occasional lapses in performance, and when these occur in operational and maintenance phases they tend to result in random failures. When they occur in earlier phases they can result in systematic failures in the operational phase.

Lack of competence can lead to systematic human error, where lack of knowledge or understanding can result in the same incorrect action always being taken under the same circumstances. (p. 32)"

There is no obvious reason to why different human reactions need more rigorous control of human factors than other industrial applications. But if it is interpreted in the light of the statement that systematic failures are mainly caused by human errors, it could be argued that control of human factors would be control of human errors. With regard to Amalberti's (2013) statement that it is not numbers of errors that leads to loss of control, but insufficient balance of recovery resources the effect of rigorous control of human error could be questioned. This research has not provided any apparent answer.

Both editions require which way human factors can impact railway RAMS shall be identified and managed, this shall include potential impact of human factors.

According to both editions the derivation of human influencing factors can be supported by consideration of the human factors listed in **Table 3** Human factors as listed in EN 50126 both editions.

The changes in the list between the editions are minor and emphasised in the table.

Table 3:

Human factors as listed in EN 50126 both editions.

Human factors EN 50126:1999	**Human factors EN 50126-1:2017**
The derivation of detailed human influencing factors *should include (emphasis added)*, but not be limited to, a consideration of each of the following human factors. It should be noted that the following checklist is non-exhaustive and *should be (emphasis added)* adapted to the scope and purpose of the application.	The derivation of detailed human influencing factors *can be supported by (emphasis added)*, but not be limited to, a consideration of each of the following human factors. The following checklist is non-exhaustive and *needs to (emphasis added)* be adapted to the scope and purpose of the application.
A) The allocation of system functions between human and machine.	A) The allocation of system functions between human and machine.
B) The effect on human performance within the system of: • The human/system interface • The environment, including the physical environment and ergonomic requirements. • Human working patterns. • Human competence. • The design of human tasks. • Human interworking. • Human feedback process. • Railway organisational structure. • Railway culture. • Professional railway vocabulary. • Problems arising for the introduction of new technology.	B) The effect on human performance within the system of: • The human/system interface. • The environment, including the physical environment and ergonomic requirements. 1 • Human working patterns. • Human competence. • The design of human tasks. • Human interworking. • Human feedback process. • Railway organisational structure. • Railway culture. • Professional railway vocabulary. • Problems arising from the introduction of new technology.

Human factors EN 50126:1999	Human factors EN 50126-1:2017
C) Requirements on the system arising from: • Human competence. • Human motivation and aspiration support. • Mitigating the effects of human behavioural changes. • Operational safeguards. • Human reaction time and space.	C) Requirements on the system arising from: • Human competence. • Human motivation and aspiration support. • Mitigating the effects of human behavioural changes. • Operational safeguards. • Human reaction time and space.
D) The requirements on the system arising from human information processing capabilities including: • Human/machine communications. • Density of information transfer. • Rate of information transfer. • The quality of information. • Human reaction to abnormal situations. • Human training. • Supporting human decision-making processes. • Other factors contributing to human strain.	D) The requirements for the system arising from human information processing capabilities, including: • Human/machine communications. • Density of information transfer. • Rate of information transfer. • The quality of information. • Human reaction to abnormal situations. • Human training. • Supporting human decision-making processes. • Other factors contributing to human strain.
E) The effect on the system of human/system interface factors including: • The design and operation of the human/system interface. • The effect of human error. • The effect of deliberate human rule violations. • Human involvement and intervention in the system. • Human system monitoring and override. • Human perception of risk. • Human involvement in critical areas of the system. • Human ability to anticipate system problems.	E) The effect on the system of human/system interface factors, including: • The design and operation of the human/system interface; the provision of user manuals etc. • The effect of human error. • The effect of deliberate human rule violation **(***e.g. where an operator ignores a rule in order to save time)***.** *(emphasis added).* • Human involvement and intervention in the system. • Human system monitoring and override. • Human perception of risk. • Human involvement in critical areas of the system. • Human ability to anticipate system problems. • *Human reaction under different operating modes (e.g. normal, degraded or emergency. (emphasis added)).*
F) Human factors in system design and development including: • Human competency. • Human independence during design. • Human involvement in verification and validation. • Interface between human and automated tools. • Systematic failure prevention processes	F) Human factors in all phases of the system lifecycle, including: • Human competency. • Human independence during design. verification, and validation. • Human involvement in verification and validation. • Interface between human and automated tools. • Systematic failure prevention processes *(e.g. measures to assure safety integrity)***.** *(emphasis added).*

The function of the list of human factors is to provide the user of the standard with support for derivation of human influencing factors. The changes in the list between the two editions are minor, whereas the first edition states that the derivation of detailed human influencing factors *should include* and the second edition states that it *can be supported by* a consideration of each of the following human factors.

The second edition has included some short explanations in parentheses for some of the bullet points, otherwise the list is exactly the same in both editions.

Findings in the List of Human Factors Within EN 50126

Although the second edition of standard has a dedicated chapter on Human Factors, which implies that human factors are an important part of the process for managing RAMS performance. The way human factors are addressed in the standard has not changed and it seems limited and appears one-dimensional. This section aims to connect the areas in the checklist and the term human error.

The definition of human factors as "the impact of human characteristics, expectations, and behaviour upon a system", leads to the notion that human factors can be understood as human performance. The focus of derivation of human factors would then rely upon performance limitations, skills, and situational awareness, that be the human's ability to identify errors, human or technological.

A) The Allocation of System Functions Between Human and Machine

The allocation of system functions between humans and technology cannot be done without some deeper considerations. It is not strictly a question of division of work, who should do what, the human or the machine where there is an assumption of fixed human and machine strength and weakness (Dekker & Woods, 2002).

Function allocation between human and machine is a question of mitigating consequences of lapses in performance which could result in random failures. People will adapt to introduction of new tools and allocation of tasks will change people's practice. People compensate to changes in an unpredicted way as all work situations carry degrees of freedom to achieve the goal of the task. A complete description of all circumstances would require a great level of detailing the tasks, and it is necessary to assume additional performance criteria should appear to be rational. (Rasmussen, 1997).

When allocation of work between humans and machines is done, it is necessary to recognise that design concepts represents ideas. There will be insufficient knowledge about future practice as a result of allocation and introduction of new tools. (Dekker & Woods, 2002) An allocation of tasks between humans and technology has to consider the design of the technology. As stated by Norman (2013) done well, it contribute towards achievement of goals, done badly it can create a lot of confusion and frustration.

B) The Effect on Human Performance Within the System

Lapses in Performance and Lack of Competence

The second edition explains human performance as occasional lapses in performance and lack of competence, lack of knowledge or understanding. The focus of lapses in performance is that they can lead to systematic or random failures, depending upon which lifecycle phase they occur. The first edition does not provide any similar explanation.

According to the second edition of the standard can lapses of performance that occurs in early life cycle phases result in systematic failures in the operational phase. Systematic failures are emergent consequences of activities which make the system to fail similarly in particular conditions, and such failures are mainly caused by human errors. Additionally, according to the note in the second edition's definition of error, human error can be "seen as a human action or inaction that can produce an unintended result" (EN 50126-1:2017, p. 11).

According to the second edition of the standard, lapses in performance that occur in the operational and maintenance lifecycle phase have consequences that tend to be random failures. Causes of random failures are situated in system function and design due to lapses of performance in early lifecycle phases.

The explanation of human performance within the system is quite circular: systematic, and random failure have their causes situated in circumstances where the failures themselves are the origin of failures due to human errors that is regarded as actions or inactions that can lead to unintended result .In order to derive factors regarding human performance within the system, point B in the checklist, it is necessary to untangle this circle of failures.

How the term system is regarded in the standard can provide some clarity with regards to systemic failures. Systems are perceived by both editions of the standard to consist of assembly of sub-systems and components, connected together in an organised way. This is not the same as system thinking, which regards systems to be more than the sum of its parts, which consist of elements, interconnections, and functional purpose. The way systematic failures are explained in the standard, leads me to assume that the standard views systems as purely technical system functions.

The human would be regarded as a component which can fail, either systematically or randomly. If human error leads to random failures, it could be possible to calculate their occurrences. But, on the other hand, if human errors are, as stated by the standard, related to actions, calculations would no longer do the job. Other measures are necessary.

The second edition also explains human performance as a function of competence, knowledge and or understanding. According to the standard lack of competence can lead to systematic human error and lack of knowledge or understanding leads to repetition of incorrect actions. To avoid such situations and by that, restrict the occurrence of human error would be to educate people. This way of thinking has deep historical roots within the railway. One major issue in the early days of the railway industry was that the public level of education was low. At least in Norway, in the late 18^{th} century it was not uncommon for people to be illiterate. In the first twenty years of the Norwegian railway history, competence requirements for railway employees were almost non-existing. With the use of telegraph devices, and especially typewriter devices, it became necessary to educate the staff. As early as 1913, the Norwegian Railway School was established, which provide education for train traffic managers, train drivers and track maintenance personnel. Implying that human performance is situated in lack of knowledge, disregards the fact that no employee, at least in Norway, works within the railway system without a certain level of education.

Business Level Policies

The definition of human factors in the standard omits social aspects as a part of the management of RAMS. However, the point B in the guiding checklist, implies that factors such as railway culture, railway organisational structure, human interworking and professional vocabulary can be part of the derivation of human factors.

(EU) 2016/798 states that railway undertakings and infrastructure managers shall establish a safety management system. This should include a consistent approach to support human performance and manage human and organisational factors. The safety management system should consider regulations and standards regarding workplace health and safety regulations.

The standard describes explicitly that general project tasks are outside the scope of the standard, and it assumes railway duty holders have business level policies addressing performance, quality, and safety. The "V-model" aims to provide a structure for planning and controlling all aspects of a systems life cycle, and the specific RAMS-deliverables of each life cycle phase are described. The "V-model" combines three dimensions of management and control. The sequence of phases, the focus of management, and requirements for documentation in all lifecycle phases. The "V-model" thus become a combinatorial presentation of different features. This leaves it up to the user of the standard to choose which dimension that would be emphasised, which contradicts the statement that the EN 50126 provides a common approach to manage RAMS elements.

C) D) & E) The Requirements for the System Arising From Human Information Processing Capabilities.

According to Rasmussen (1990), it is difficult to prove empirically the requirements of reliability and safety that the hazards' involved in large scale system operations leads to. For that reason, the design of such systems must be based on models that are used to predict the effects of technical failures and human errors. Mathematical calculations based upon the knowledge of quantitative measurable input-output variables are effective methods for verifying designs and optimising functions.

Structural models of input-output-descriptions of human error are based on models of information processing. That is, how information flow is established, processed, and then materialised into action (Read et al, 2021). Functional and situation-based models are based on interaction between people and their environment. Assessment of human error will be influenced by the model underlying the assessment (Read et al, 2021). Point C, D and E are about requirements on the system, requirements for the system arising from human information processing capabilities and the effect on the system of human/system interface. This includes factors such as human competence, effect of human errors, effect of deliberate human rule violation, mitigating the effect of human behavioural changes, human reaction time and space, human reactions to abnormal situations etc.

Derivation of requirements of the system arising from human information processing capabilities implies that human error can be analysed based upon models of input – output structures.

As stated by Rasmussen (1982) human information processes are not solely an input-output situation where the human is a passive recipient. Trained people ask questions to the system biased by their experience and immediate expectations.

Human error itself is an elusive notion. In language terms "error" constitutes something that went astray, Read et al (2021)opine. According to Rasmussen (1982) human error is defined after an event, based upon expectations of the function of the system. In a work situation, human actions are reasonably predictable when those actions are close to the system. For example, a train traffic controller close to the signalling system used to set the route of a train and hence a train traffic controllers' actions are reasonably predictable. The further away from the technical core, the more degrees of freedom of performance the employee has to do their job (Rasmussen, 1990). For example, the train traffic controller's manager, their actions related to their work are less structured by the immediate surroundings. It is less important whether a report is written, or a decision is made early or late at their shift, as long as the report gets delivered within the timeframe or the decision is made. What can be judged as human error becomes less certain, it becomes more difficult to establish a clear connection between correct and incorrect actions.

The implication of this is that even if human behaviour can be predicted by expectation, e.g. it is possible to expect that the train traffic controller will manage train traffic, and the manager to write the report. It would be difficult to calculate which precise actions the train traffic controller or the manager would embark upon. The train traffic controller would take into consideration the current situation, like delays, train or train staff shortage, numbers of passengers etc. The manager may have to address other pressing issues, e.g. lack of staff due to sick leave, than writing the report.

It would then be even harder to predict the occurrence of human error by calculation, especially if a human error only can be identified after the fact. That is after an action is taken, and the judgement of whether the action resulted in an error are based upon a derivation from an expectation as a result of an action. This would require knowledge, in advance, about possible alterations of actions, what possible results those action can lead to, and whether those would be erroneous or not. In other words, it would be necessary to know the future.

A calculation would also have to take into consideration which kind of error, as stated by Amalberti (2013), the most frequent errors are routine errors, which are just as frequently detected and corrected with no further implications. This detection and correction of errors also alters the persons actions. While frequent routine errors are easily detected and corrected by small changes in a person's actions and less frequent errors demands more attention, both errors and their detection and recovery strategies alters the person's actions to some degree. A calculation of the probability of an error to occur would be complex and I doubt it would have any practical value. It is not human information processing capabilities that raises requirements to a system, it is the system that raises information process requirements on the human.

F) Human Factors in all Phases of the System Lifecycle

Point F in the checklist focuses upon "human factors in all phases of the lifecycle", to me this relates to the requirements within the standard. What stands out are the subpoints:

- Human independence during design, verification, and validation.
- Human involvement in verification and validation.

According to the second edition independence between roles are required to reduce probability of people in different roles suffering from the same misconceptions.

Human error in this case relates to what Amalberti (2013) states as a subcategory of errors of errors of rule activation and errors of representation, termed as errors of fixation. Where human errors occurs as a result of a team of people fixates on the same perspective of a problem and the possible solution. According to Amalberti (2013) detection and recovery strategies in such situations are based upon the team's ability to adopt different view of the problem in real-time.

Discussion

The need for technical standardisation in railways in Europe has its origins in the EU's decision to establish and develop trans-European networks within transport, telecommunications, and energy infrastructure. The EC verification scheme has two purposes, one is to ensure technical compliance with European requirements, the other is to contribute to transparency in trades.

The decision to develop the Community's railways meant that in addition to serve as a means of transport, the railway itself should be opened up to the free market. This initially applied to high-speed railways but was later expanded to include conventional railways. The EC verification are done in accordance with technical specifications on interoperability (TSI) where the basic parameters are determined for the entire Community, particularly with regard to components and interfaces.

The development of TSIs has been and are taking place in stages, and subsystems such as environment, users and operation are only subject to technical specifications for interoperability (TSIs) to the extent necessary to ensure interoperability within infrastructure, energy, control, and control and signalling and rolling stock. The verification should enable the authorities responsible for permission to set in service means to ensure that the result of the design, construction and commissioning stages are in line with the applicable technical operating regulations. It should also provide producers to count on equal treatment regardless of country.

Even though the standard has been revised and a second edition is issued, with establishing a separate part regarding risk assessment and safety management, much of the fundamentals which the standard rest upon have not changed. EN 50126-2:2017 clearly states that operators and their actions are not considered as a part of the technical system. Technical systems are defined as a product or an assembly of products. The design of relevant interfaces regarding interaction between the operator and the technical system must be described, but the focus is the functionality of technical components.

The purpose is to create a clear distinction between hazard assessments that are concerned with the technical system itself, and risk assessments with regards to the use of the technical system. This reinforces the standard's technical focus, where human factors and human errors are not part of the process to achieve a dependable RAMS performance. Human actions can, according to EN 50126-2:2017, be expressed as application conditions.

According to EN 50126-2:2017, such a distinction between assessment of hazards for the technical system, and risk concerned about the use of the system contributes to simplify modelling, reducing complexity and clarifying responsibilities between actors. This is true for specific assignments regarding explicit projects of development or renewal of infrastructure. Establishing contracts with suppliers and thereby clarifying the responsibilities regarding deliverables is outside the scope of the standard. EN 50126-1:2017 clearly states that general project tasks are not part of the focus area of the standard.

The responsibility for meeting regulatory requirements regarding interoperability, technical specifications, and authorisation in Norway rests with the infrastructure manager (FOR-2011-04-11-388; FOR-2021-09-08-2740; FOR-2021-09-09-2742). This means that the need for a standardised process lies with the infrastructure manager, who also has a clear responsibility with regards to general railway safety, which includes people working in the railway system.

From the view gained from this research, informed by praxis, this creates an artificial distinction between RAMS performance and operational safety. Which makes it unclear who the standard aims to serve and who the readers of the standard are.

Safety Levels

While a minimum safety level is established for the subsystems defined by technical specifications for interoperability (TSI), these requirements do not deal in detail with the regulation, management, and supervision of safety within the rail system.

Between the first edition and the second edition of the standard, both European and Norwegian railway regulations were revised. The European Safety Directive (2004/49/EC, EU 2016/798) was established to equalize differences with regard to requirements regulation, management, and supervision of safety at a system level. Development of common safety targets (CSTs) and common safety methods (CSMs), which enable assessment of the safety level and performance of operators at Union level, as well as Member States, are an important part in the further growth of the railway system.

Infrastructure managers and railway undertakings were to implement a safety management system that meets the Community requirements. The management system should include measures to encourage improvements of the protection of the safety and health of workers engaged in rail transport.

It is not possible to trace this general change of railway safety in the EN 50126 standard. The reasons for this, are related to the fact that the management of RAMS performance is perceived not to be influenced by this i.e salience of EN50126. RAMS performance is linked to the technical components' properties and technical development of components and, to a lesser extent, how society wants to use the railway.

On the other hand, societal changes, such as the use of the railway, the development of rules, research and technology will affect how processes are carried out. Despite the fact that it is possible to trace a certain degree of development in the standard, through an increased focus on risk analyses and a somewhat extended explanation of actors, I had expected a more obvious change, given the nature of the changes in railway operations across the European Union.

For example, the latest edition extends, to some degree, the description of how RAMS performance in a system is affected by errors, by adding a notation about how human error can be understood in its definition of error. Human error is seen as "a human action or inaction that can produce an unintended result" (EN 50126-1:2027, p. 11). In my view, this description goes in the opposite direction of the development within safety science research. Where development has moved away from the mindset that people are a component that fails, and that the causes of accidents have their origin exclusively in either technical or human failure.

I had expected that the developments within safety science and with this, how human errors are discussed with regards to accidents, to appear in some form in the subclause 5.6.4 Human Factors. With regards to derivation of human influencing factors, the changes within the different editions of the standard are practically absent. Both with regard to the overview of connections between generic factors that influence RAMS, but also for the description of how to derive detailed influencing factors.

The latest version does have a section which describes that the derivation of detailed factors must be carried out as a structured process which may suggest a certain development. The recommendation to use cause/effect diagrams for such a derivation shows that in practice the standard has not changed the basic assumptions of humans as a component nor recognition of the presence of uncertainty or complexity in rail operations. Reflecting the non-linear nature of these. On the contrary, it seems that this view of humans is reinforced as is a prevalence for reductionism through linearity. Attainment of in-service availability of the railway system is, according to EN 50126-1-2017, based on optimising the reliability and maintainability of the components (p. 25), and less on how the railway is optimised as a transport system.

On the contrary, optimising the railway as a transport system as a workplace is not only dependent on the reliability of components, but also on people's ability to manage the system in various situations. The standard's definition of human factors avoids the social aspects involved in the rail transport system. Which is in contrast to how ERA defines human factors, ERA uses the same definition as The International Ergonomics Association. In this definition, the focus is not on human characteristics as a source of error. The focus is on the application of experience, knowledge and research as a basis for improving human well-being and optimising overall system performance. This provides a completely different baseline for how human error is understood. Human errors and physical and mental limitations are, after all, only a small part of what constitutes human factors. People are not only affected by the technical aspects of their surroundings, but also intangible aspects such as relationships, emotions and life situations.

People's actions are thus not viewed as a question of failures, but people's ability to diagnose and find solutions to challenges. An important aspect in this context is people's ability to learn from mistakes. In uncertain complicated situations, trial and error is a necessary prerequisite in order to understand the state of a system and find appropriate measures to make systems to function as intended (Rasmussen 1990). These are conditions that are well known and discussed in the research on human error. The strong focus on errors as a cause of system failure within the standard contributes to this dimension of human characteristics being overlooked in the derivation of human influence factors.

Research limitations

My analysis of the standard is a document study, where I started with the content of the EN 50126-1:2027 and subclause 5.6.4 Human factors. My initial plan was to interview different professionals who are users of the standard. It was not possible to obtain interviews, and I had to alter my research into a document analysis.

Some of the strength of document analysis is that data can be selected rather than collected. A weakness with this is the possibility to choose non-relevant documents and documents close to "the action" can be restricted for different reasons. In my experience as a practitioner working with RAMS in small and medium-sized projects, I have access to documents which I cannot implement into my research as they are organisational protected, hence not available to the public.

In order to respect this, I have focused my research of documents that provide context for the EN 50126 at a public available level. Which means that my findings in my research are affected by this. The research was focused upon a macro societal level. That is at a level of publicly available assessments, and not their underlying assessments. For example, I have not researched letters or other written background assessments requested by the royal commission of inquiry that were set up in the aftermath of the Åsta-accident, only the publicly available report the *NOU 2000:30 Åsta-ulykken, 4. januar 2000 — Hovedrapport*. To protect the people involved documents such as witness statements and technical assessments reports are protected by the Public Administration Act. The Act have some exceptions, but in order to gain access there has to be an explicit reason. Being a private student researcher is not a sufficient reason.

Generally Public Assessments, NOU's are requested assessments by the government. The work of an NOU is carried out by special committees and mainly consist of politically independent experts and researchers in the relevant field. Such committees are usually supplemented by representatives from businesses and voluntary organizations who will be affected by measures in the relevant problem area. In some cases, representatives from the political parties are also participate in these committees. However, it is the professional, not the political considerations that are the foremost characteristic of these assessments. If a NOU report would be the subject of political processing by the initiating ministry, it normally ends with a proposal to the Parliament where it is the drafted proposal, not the NOU itself, that forms the basis for the Parliaments further considerations. Such drafts, and their political discussions leading up to a decision, either it would be issuing a law or other measures are publicly available. This means that even if my research are restricted by lack of access, it is possible to deduce how topics are treated. This only applies to a national level of administration.

Establishing and revision of Act's are subject to consideration in the Parliament, and such consideration is well documented and publicly accessible. Regulations like the FOR-2011-04-11-388 Railway Infrastructure Regulations, the processing of this type of document is often delegated to a public entity. Assessments done with regards to changes in regulations are generally protected by the Public Administration Act. Even if some of the considerations are available in official journals, navigating such journals are not easy and often requires additional access which usually are obtained through profession. How topic are discussed and what measures taken within an organisation are not accessible.

This means that my document research was restricted and consequently my findings can be restricted as well.

The scientific field of safety and human factors has stretched over a long period of time, and there are several prominent researchers, all contributing to the field of knowledge in their own way. As a novice researcher it is easy to be overwhelmed, and choosing relevant literature from this vast well of knowledge can be difficult. Resulting in the fact that some researchers are left out and others taken into consideration. This means that my analysis of what constitutes as human error does not include all the existing knowledge, my research once again are restricted. There is a real possibility that I have missed important research, which could have impacted my findings.

My document analysis has included documents and books of railway history. Such stories are not written as contributions to a scientific debate, but as narratives. Those narratives often includes collected facts, like references to procedures, decisions, pictures and so on, which means that they contain a lot of reliable information. Such historical documents are aimed at telling a story, and not scientifically discuss a topic. They did provide my research with historical context regarding the status and development of the railway industry as a great contributor for economic growth and mobility of humans and goods . Documents of history can also be affected by external factors such as data which are lost or destroyed over time.

Despite the discussed restrictions in my research, it has been possible to shed some light on my research question: If the outline of knowledge about human factors used in the EN 50126-1:2017 are sufficient to understand human errors.

Conclusion

This research was aimed at the process standard EN 50126-1:2017 Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) Part 1: Generic RAMS Process.

My specific research question was "Is the outline knowledge about human factors used in subclause 5.6.4 Human factors in the RAMS standard (EN 50126-1:2017) enough to understand human errors?" In order to find answers, I had to reach outside the standard itself as well as interpreting the content of the standard.

The standard is a harmonised standard, and it is the technical specifications of interoperability (TSI) regulations the standard provide the presumption of compliance with. The EN 50126 standards are in them self not really explicit about what regulation it is expected to provide compliance. This has to be interpreted in the light of development of high-speed railways, the European decision to facilitate the adoption of the Community railways to the needs of the Single Market, as well as both the national and European development of regulations for the railway industry. The fact that the use of the standard are in Norway regulated by two different regulations enhances even further the question of which regulation the standard aims to satisfy. An important aspect is the standards aim to provide a standardised approach to management and control of the RAMS performance of the system. As the presentation of the "V-model" for structure planning, administration, control, and monitoring suggests three dimensions of management and control which in practice leaves it up to the user to choose which dimension that would be emphasised contradicts the aim for a standardised approach. It could be argued that this undermine the standards role as a mean to ensure a consistent level of safety within the railway industry.

While it make sense to set technical requirements in order to ensure consistent product quality, it does not change the fact that in real use, all systems, will at some point operate in unexpected or unplanned ways. Both editions recognise the fact that humans can impact a system both in a positive and negative way, but the strong focus upon errors as a cause of system failure does not recognise people's ability to make adaptions in order to prevail the function of the system. This would be ensuring that the railway continues to uphold its function as a transport system, regardless of intended technical product quality. A technical high-quality railway in the sense of predictable factors of failures does not do anything if no one uses it. It is only through use the railway becomes a transportation system. The standard does not reflect that the purpose of a system is not necessarily explicit stated, as recognised by Wright (1993/2008). This way of thinking about systems are omitted by the standard, as it focuses upon systems as components and their causes of failure. The standard says little of how systems affects people, and the focus is upon human errors as a reason for systems to fail.

The standard defines human errors as human action or inaction that can produce an unintended result. Humans then becomes a source of trouble, regardless of what they do or not. The standard states that humans can react differently in different situations, which requires, according to the standard, rigorous control. It is unclear what would constitute as control of human factors, beside application of appropriate processes, methods, and organisation. The standard does not offer any explanation to what would be considered as appropriate in this context. It is also unclear if the standard really means human factors, it seems as what it is really addressing is human error, and by extension human behaviour.

Both editions of the EN 50126 standard provide information of human factors in the form of a checklist and states the necessity to derive such factors when designing and building railways. The second edition states that the derivation of detailed factors should be carried out as a structured process, suggesting the use of cause/effects diagrams. Such diagrams are useful tools where the connections between effects and causes are linear. In circumstances where the nature of cause and effect are complex non-linear such diagrams can lead to a simplistic assumption that using the checklist is all that is needed to derive human factors. The implication can thus be that human issues are taken lightly and maybe low hanging measures to optimise the system are missed.

The railway system is by nature a complex system, sensitive to interactions between people, technological developments, and climate challenges. The future railway needs to take all of this into account in further development of the transportation system. The general technological development are moving towards a significant interaction between people and digital solutions both with regard to condition detection and in operation. This raises the need for a better understanding of the interactions, and the way humans are viewed as a source of trouble with regards to factors which could influence the RAMS of the system disregards people’s ability to diagnose and find solutions.

Human factors is considered by the standard to be a core aspect within an integrated management process it seems as this goes as far as to manage human actions that can lead to an unintended result.

It seems like humans are considered to be more trouble than treasure in the eyes of the standard.

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Appendix

The Standards of Railway applications, Reliability, Availability, Maintainability and Safety (RAMS standard)

According to the CENELEC website, Standards are defined as:

> "… a document, established by consensus and approved by a recognized body that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context. Standards should be based on consolidated results of science, technology, and experience, and aimed at the promotion of optimum community benefits."

Both European Standards Bodies CENELEC and the national CEN, the Norwegian Electrotechnical Committee (NEK) emphasise that standards are developed and governed by the principle of consensus, openness, transparency, national commitment, and technical coherence.

The standards of Railway applications, Reliability, Availability, Maintainability and Safety (RAMS standards) are a set of standards:

- BS EN 50129:2003 Railway applications —Communication, signalling and processing systems — Safety related electronic systems for signalling.

- BS EN 50128:2001 Railway applications —Communication, signalling and processing systems— Software for railway control and protection systems.

- NEK CLC/TR 5016-3:2006 Railway applications – The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS) – Part 3: Guide to the application of 50126-1 for rolling stock RAMS.

These parts of the RAMS-standard set are outside the scope of this thesis.

The relevant part of the Reliability, Availability, Maintainability and Safety (RAMS standards) are:

First edition:

- BS EN 50126:1999 Railway applications – The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS).

Second edition:

- BS EN 50126-1:2017 Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) Part 1: Generic RAMS Process.

- BS EN 50126-2:2017 Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) Part 2: Systems Approach to Safety.