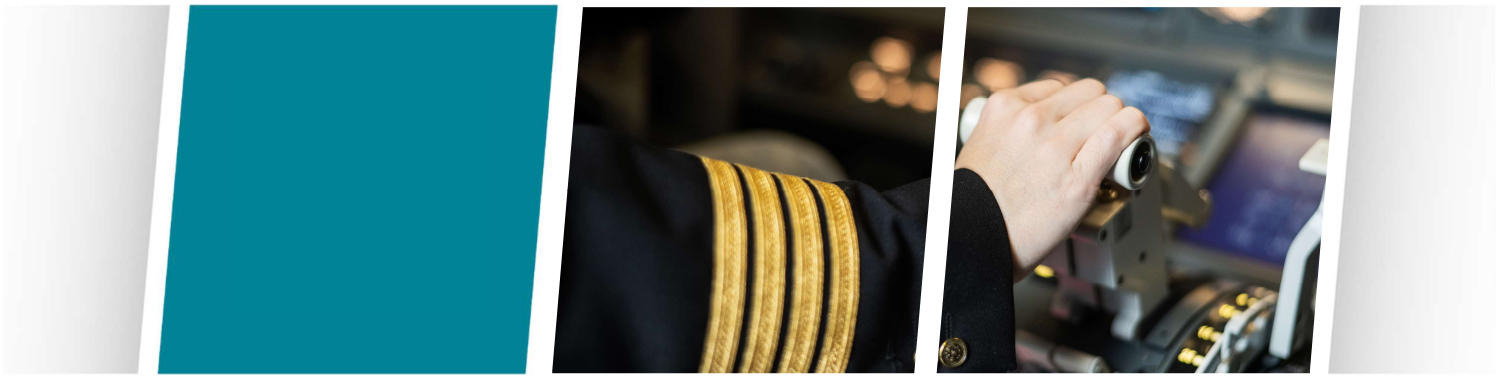
Norwegian Safety Investigation Authority



Human factors in NSIA's safety investigations

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The object of NSIA's investsigations is to clarify the sequence of events and causal factors, elucidate matters of significance for the prevention of accidents and serious incidents and to make possible safety recommendations. It is not NSIA's task to apportion blame or liability.

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Introduction

Purpose

This thematic booklet provides an insight into how the Norwegian Safety Investigation Authority (NSIA) investigates human factors (HF) in connection with an accident.[1] The scope of this part of the NSIA's safety investigations varies depending on the nature and complexity of the case.

The purpose is to identify and explain factors that shed light on how the people involved in the sequence of events acted the way they did, and the factors that may have impacted their level of functioning at the time of the accident. The investigation should also say something about how others in the same situation could have acted, i.e. compare actions in the sequence of events with normal, expected and ideal practice.

The NSIA has developed an interview guide for human factors[2], which is based on and complements the model presented in this document.

Theoretical platform

Theory and research dealing with the interaction between man, technology and organisation (MTO) is of great importance to the NSIA's safety investigations.

The NSIA's investigations are intended to contribute to safety at an overarching level and lead to lasting improvements to systems, designs and work processes. That entails not only looking at the sequence of events and the triggering mechanisms, but also to investigate contributing factors at different levels of the socio-technical system[3] that may help explain how and why an accident happened. These are factors that have not necessarily had a clear cause-and-effect relationship, but that are considered to have increased the risk of an accident (for example fatigue/exhaustion, pressure to get the job done, unclear work descriptions, lack of supervision etc.). A more detailed description of the NSIA's framework and analysis process for systematic safety investigations (the NSIA method) is available here: https://www.nsia.no/About-us/Methodology.

It is particularly research on situational awareness that has shaped the NSIA's approach to investigating human factors in accidents. An introduction to situational awareness, technology and organisation can be found in e.g. Endsley, M.R. & Jones, D.G. (2012).[4]

Human factors introduce the subjective element as a necessary, legitimate part of the safety investigation. To bring us closer to an explanation of how and why an accident occurred, it will often be necessary to understand how those who played a key role in the incident perceived the situation there and then, and how they acted based on that understanding.

Three main questions

The investigation of a person's level of functioning in connection with an accident is based on the sequence of events. In order to ensure that our investigation of the person's functioning is relevant to clarifying what may have contributed to the accident, we ask three main questions:

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[1] The description in this document also applies to the investigation of serious incidents.
[2] Interview guide HF english version v2.0
[3] See Rasmussen, J. (1997): Risk management in a dynamic society: a modelling problem. Safety Science Vol. 27, No 2/3, pp. 183–213.
[4] Endsley, M.R. & Jones, D.G.: 'Designing for Situation Awareness. An Approach to User-Centered Design.' CRC Press, Taylor & Francis Group, Boca Raton, FL, USA, 2012.

1. Which of the person's decisions and actions seem to have had the greatest impact on the sequence of events?

   This should be based on a systematic overview of what happened, for example in the form of a STEP[5] diagram. STEP diagrams will not be discussed in this booklet.

2. What situational awareness were these decisions and actions based on?

   Here, we would like to gather as much information as possible about the person's situational awareness before and during the accident:

   - What information did the person perceive through their senses?
   - How did the person use this information, combined with e.g. their own skills and experience, to form an overall situational awareness?
   - Was their understanding of the situation quick and intuitive or more gradual, conscious and based on available information and skills? Try to get the person to describe their own thinking at the time the incident occurred.

   It is often a good idea to let the person talk about their situational awareness, decisions and actions relating to a specific incident in the accident. Then you can interview them about the next incident in the accident they were involved in.

   This will often work better than asking someone to explain everything they saw, heard, smelt, felt etc. at Level 1 throughout the accident, and then to proceed to Level 2 and ask for their understanding of the situation at all stages of the accident etc.

3. What factors have or may have affected the person's situational awareness, decisions and actions?

In the following, we will first look at Question 2 (situational awareness, decisions and actions), before moving on to Question 3 (factors that may have affected the person's functioning).

[5] *Sequential Timed Events Plotting*

1. Model for human factors (HF)

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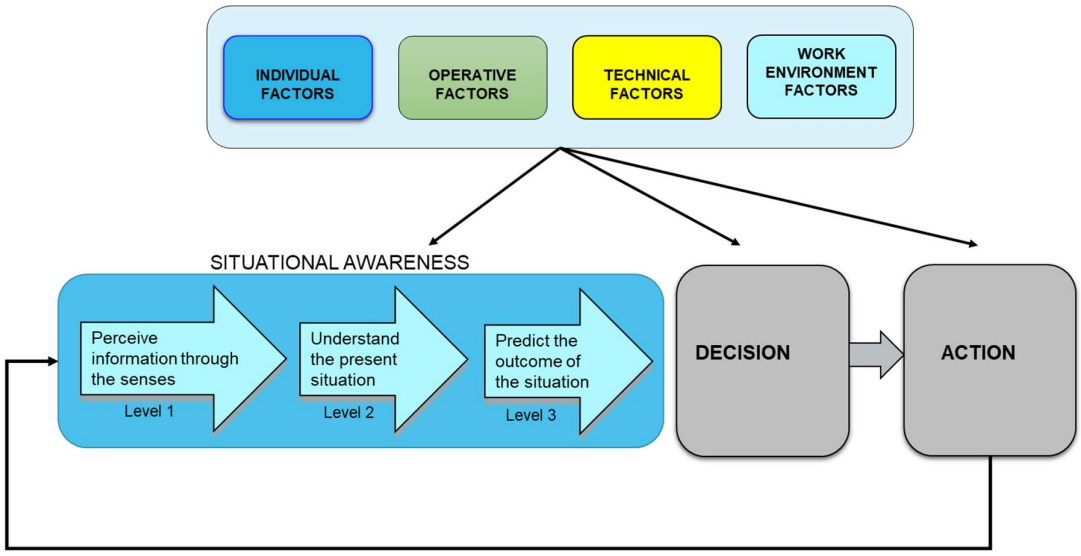
1.1 Introduction

This chapter provides an overview of what areas of human factors (HF) we consider investigating when an accident has occurred. The NSIA's accident investigators have access to internal HF specialists who can help to clarify what areas of investigation in this field are most relevant for the accident in question.

The NSIA has prepared a model based on the research of Mica Endsley,[6] which it uses for the investigation of human factors; see the figure below.

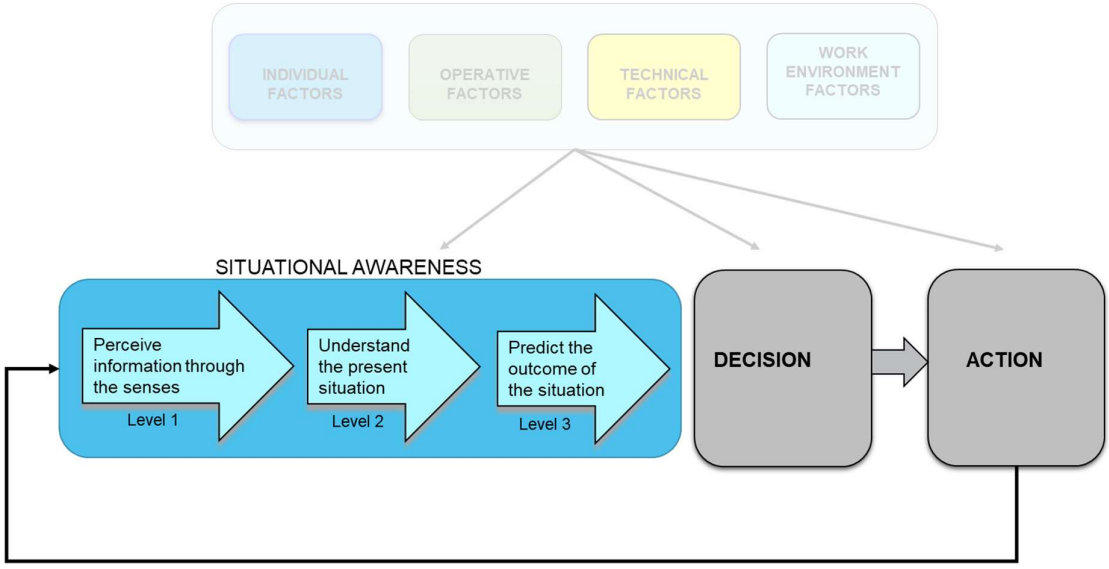


The model consists of two main elements:

1. a continuous process of situational awareness, decisions and actions, described by Endsley & Jones (2012)
2. four main groups of factors that may have affected the person's functioning in this process. The factors may, in principle, have influenced one or several stages of the process.

[6] *Endsley, M.R. & Jones, D: 'Designing for Situation Awareness. An Approach to User-Centered Design.' CRC Press, Taylor & Francis Group, Boca Raton, Florida, 2012, 2nd edition*

1.2 Situational awareness, decisions and actions



A frequently used definition of situational awareness is based on Endsley's original wording:

> *Perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future* (Endsley, 1988).[7]

In brief, situational awareness means being aware of what is happening around you and how the situation will develop. Situational awareness can be broken down into three levels: perceiving information through the senses (Level 1), understanding the present situation (Level 2) and predicting the outcome of the situation (Level 3).

We can use the example of a driver driving along a country road. The driver spots an animal near the side of the road (perceives information through vision, Level 1). The driver understands that the situation has changed and that vigilance is needed (understands the present situation, Level 2). The driver also anticipates the possibility of the animal crossing the roadway and that there is a risk of hitting it (predicts the outcome of the situation, Level 3). The driver therefore decides to slow down and pass the animal at low speed (decision), and does so (action).

When the person decides to act and carry out the decision, the action may impact the surroundings in a way that changes the situation for the better or worse, or it may have no noticeable effect at the time. Under any circumstances, the model illustrates how the person continuously collects information from their surroundings and assesses whether or not their situational awareness needs to be adjusted and whether to carry out one or more actions. Decisions and actions are therefore important to situational awareness and an important topic in most of the interviews we conduct.

The basis for forming a situational awareness is created by perceiving the 'raw' information through the senses, for example looking through a window, observing instrument panels, sensing vibrations, movement or smells – in other words, everything you can sense.

At Level 2, the information is compiled and interpreted to form a picture of the situation. The combination of vibrations and smell, for example, suggests that there is something wrong with the

[7] *Endsley, M.R.: 'Design and evaluation for situation awareness enhancement.'* In Proceedings of the Human Factors Society 32nd Annual Meeting (pp. 97–101), 1988, Santa Monica, California: Human Factors Society

engine. At Level 3, the operator predicts how the situation will evolve, for example that the engine is about to stop.

Situational awareness is a continuous process, where each level affects the next. An operational environment will contain large amounts of information at any given time, and it is difficult for the operator to grasp everything that is going on. The operator uses his understanding (Level 2) and prediction (Level 3) to guide the search for information (Level 1) he considers important. Understanding and prediction enable him to interpret and understand the information received through his senses, quicker and usually more accurately.

In the example above, the operator will perhaps, based on his understanding that the engine is about to stop, direct his attention and thereby senses to finding a suitable place to stop. This enables his situational awareness to be continuously updated and refined, which in turn provides the basis for well-considered decisions and actions.

If a driver observes a bus in a bus lay-by and knows that it is a weekday, the time at which school starts and that there is a school on the other side of the road, the driver will, even at some distance, more quickly identify something moving on the other side of the bus, such as a child crossing the road. The continuity of the process is illustrated in the model with an arrow pointing from the action back to Level 1.

Many tasks that require situational awareness are learnt and practised to the point where the task can be accomplished almost without thinking. Driving a car is undoubtedly a task that requires situational awareness. Nevertheless, most people will, with some practice, be able to do it without much conscious thinking. When performing such well-rehearsed tasks, a person's situational awareness will move very quickly from Level 1 to Level 3 and back to action.

Other tasks, such as navigating a narrow, heavily trafficked fairway in reduced visibility, may be less 'automated' in the operator's mindset. In that situation, he will have to constantly retrieve new information about course, speed, drift and other vessels (Level 1), form an overall picture of the distance to other vessels and shallows (Level 2) and predict when to make the next turn or adjust propulsion (Level 3). The less 'automated' a task is, the more mental capacity it requires, leaving less capacity for the operator to perform other tasks simultaneously.

When interviewed, an operator cannot always account for all the levels of situational awareness in a given situation. This is due to the speed at which the situational awareness has been formed, decisions made and actions taken – on reflex or instinct. Parts of the process may have been more or less instinctive. In addition comes the normal forgetting curve, which means that information is lost from the memory of the person concerned. Difficulties accounting for situational awareness, decisions and actions are therefore common, and normally not a sign that the operator does not want to cooperate during the interview.

2. Factors that may have affected the person's functioning

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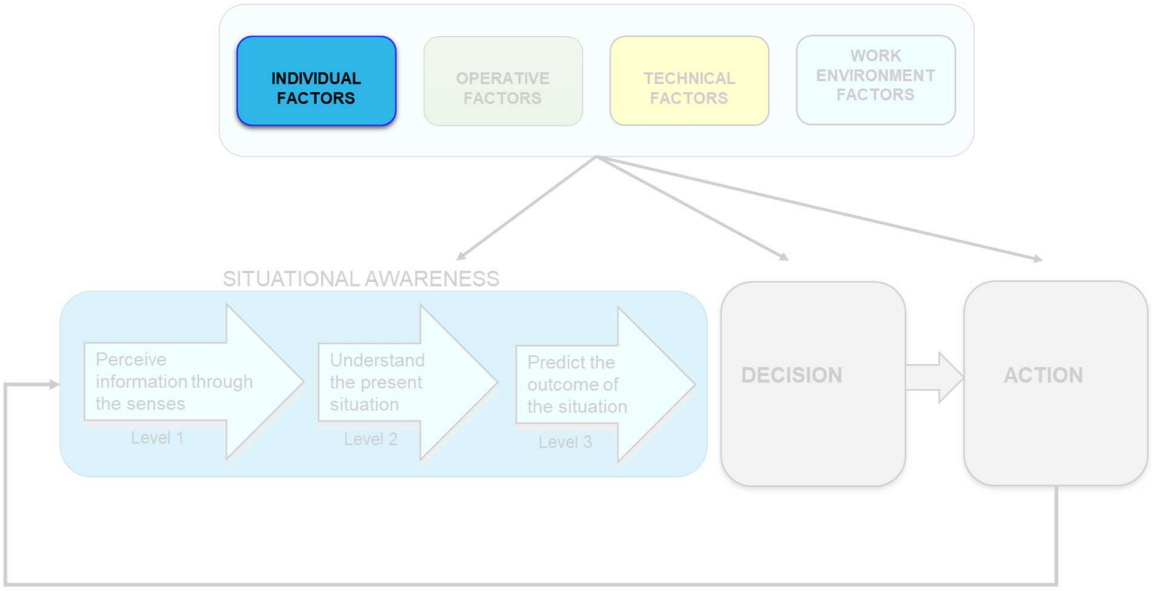
A number of factors may have affected and changed a person's situational awareness, decisions and actions during the process. We will review some common factors here as an illustration, but the list of factors is not exhaustive.[8]

2.1 Individual factors



People differ in many different ways. Some see better or have a better sense of hearing than others. Some have been in their job for a short period, while others have many years of experience. Some remember better than others, and so on and so forth.

Forming an impression of the persons involved in an accident by collecting available data about their level of functioning is therefore important. These are some of the individual factors that may affect how well or poorly a person functions with regard to situational awareness, decisions and actions:

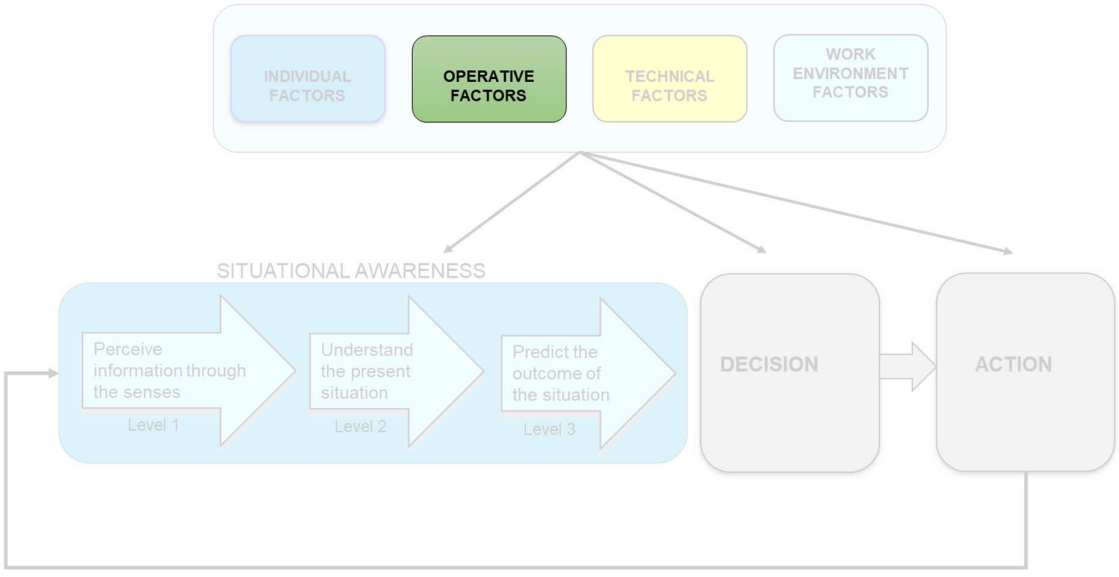
- How well did the person see and hear, did they need glasses or a hearing aid, were such aids used and did they compensate for the sensory impairment as intended?
- What skills did the person have with regard to the tasks they were set to perform at the time of the accident? How much training had the person received?
- How much experience did the person have of this type of work?
- Was the person under the influence of medication or intoxicants?

[8] *It is difficult to draw a clear distinction between a person's thought processes and external factors that influenced these processes in a given situation. The distinction is nonetheless useful here to illustrate use of the model as a mapping tool in a safety investigation.*

- Was the person tired or exhausted? There are a number of questions that need to be considered in this context, such as:
    - number of hours of sleep the night before the accident
    - quality of sleep in the last three day
    - sleep deficit accumulated the last three to five days
    - how well the person has recovered after recently accumulating a sleep deficit (two nights of good sleep is usually required)
    - age and experience (older drivers experience sleep problems more often than younger drivers)
    - the time of day the accident occurred.
    - how many consecutive hours the person had worked when the accident happened
    - Was the work situation characterised by passivity and low activation of the nervous system? That may contribute to increased fatigue.
    - Did a combination of the above-mentioned factors result in increased fatigue and exhaustion?
- Was the person's behaviour and actions compatible with what is known as complacency, meaning satisfaction with their own functioning, resulting in in lack of vigilance and active efforts to prevent unnecessary risk?

Based on the individual factors identified in the investigation, the NSIA assesses the extent to which they may have affected the person's functioning. We clarify how we believe situational awareness, decisions and actions were affected, and how this can help explain why the accident happened.

2.2 Operative factors

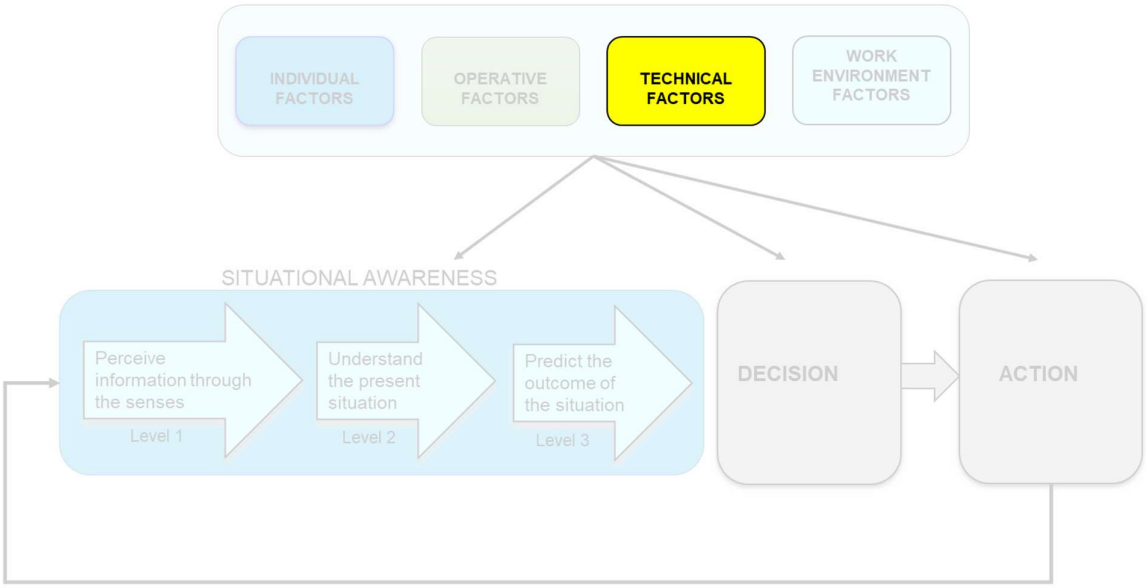


Operative factors that may affect situational awareness, decisions and actions include:

- Operative goals, for example expectations of carrying out a transport assignment within a given deadline, or conquering a geographical area during a military exercise.

- Tasks: Were many sub-tasks required to be carried out at the same time, thereby overloading the person's working memory, or was the amount of tasks manageable? How difficult was it for the person to perform the tasks?
- Distracting and attention-demanding elements in the means of transport,[9] for example smartphones, map systems, alarms or passengers disturbing the operator.
- Distracting and attention-demanding elements outside the means of transport, for example other actors in the transport system contacting the operator at a time that disrupts the formation of a situational awareness.
- Was there heavy traffic, did the person feel pressed for time, were there other notable elements that characterised the situation at the operative level?

2.3 Technical factors

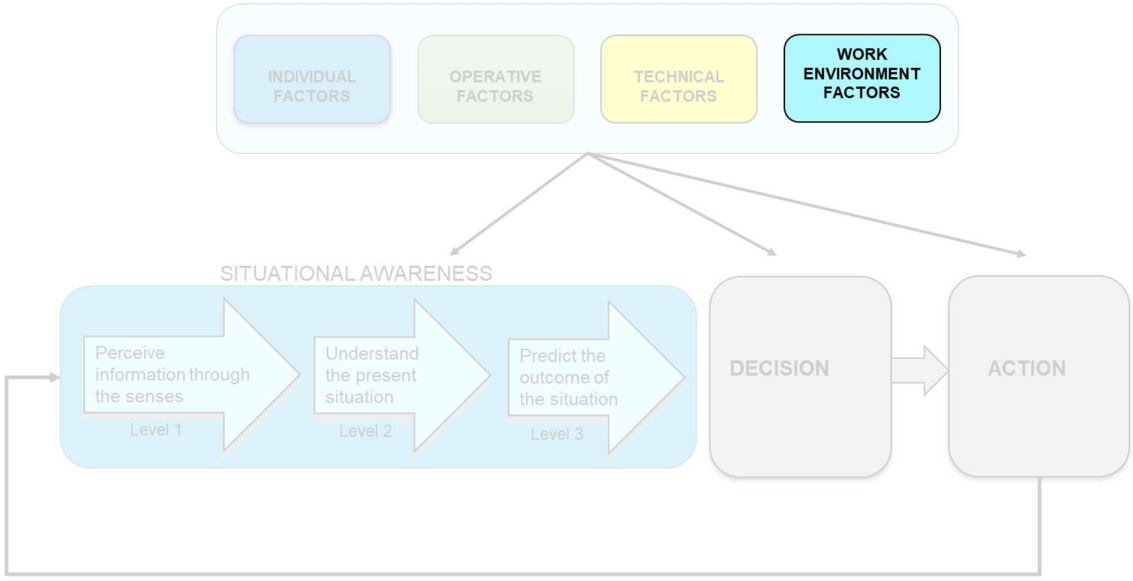


Technical factors that may have affected the person's functioning include:

- breakdown of components of systems in the means of transport, for example engine failure
- the workings of electronic notification systems
- the person's degree of automation when the accident occurred
- how familiar the operator was with the possibilities and limitations associated with the degree of automation used
- cognitive ergonomics, for example what information was presented to the operator, and how. How user-friendly was the man-machine interface?

[9] *Includes means of transport such as aircraft, vehicles, maritime vessels and rolling stock.*

2.4 Work environment factors



There are many different characteristics of the work environment that may have affected the person's functioning when the accident happened. Some examples are provided below. The work environment factors that may have affected the person's functioning and that may be relevant to understanding the accident are assessed in each individual case. In most cases, there will be a few factors that it will be natural to look into in more detail.

2.4.1 PHYSICAL WORK ENVIRONMENT FACTORS

Noise where the operator was located may have a bearing on an accident in more than one way. It can make it difficult to perceive messages given in person or over the radio, and audio alarms and sounds from faulty equipment. Noise can also make a person more tired and increase their level of stress over time.

Noise is therefore a factor that can limit what is auditively perceived and thereby reduce a person's ability to function adequately with regard to situational awareness, decision-making and actions.

The temperature where the operator was located can also be a relevant topic in a safety investigation. This will be natural if there is reason to believe that too high or too low a temperature over time has affected the person's mental functioning, for example in the form of reduced cognitive capacity or a reduced ability to physically perform an action.

A third example of physical work environment factors is lighting conditions. The operator may not pick up relevant information because of poor lighting, for example when operating heavy equipment such as cranes or winches. If the lighting prevents the operator from seeing well enough to perceive all risk factors associated with the work, the risk of accidents also increases. The same applies if the operator has too much light in his eyes, is blinded and does not see everything necessary to avoid dangerous situations.

2.4.2 PSYCHOLOGICAL WORK ENVIRONMENT FACTORS

On the one hand, there are requirements and expectations of the work an operator performs, and, on the other hand, there are resources available to enable him to fulfil these requirements and expectations. If there is a good balance between requirements and resources, most employees experience job satisfaction and a sense of mastery.

If there is a perceived imbalance because the requirements exceed what someone is capable of, however, the most common reaction is an increased stress level and workload, entailing a risk of degraded performance and physical and mental exhaustion if the imbalance persists over time.

A clear link between high stress levels and reduced cognitive capacity has been documented. The person's functioning in the situational awareness process is thereby reduced. The same applies when the stress level is too low, which is observed for drowsiness and the performance of monotonous tasks over time.

Because of these correlations, factors such as time pressure, workload and unreasonably high requirements of goal attainment are examples of work environment factors that may affect a person's functioning in the situational awareness process and that may explain why the accident happened.

Various social work environment factors may also affect the person's functioning in the situational awareness process. For example:

- How closely was the person followed up by their immediate superior? Was that person available for questions, support and guidance? Is it possible that the manager's leadership style affected the person's situational awareness and actions?
- Cooperation and conflict make up another group of social work environment factors. Was the flow of information and distributed situational awareness good enough between the persons of interest and other internal or external stakeholders? Were there disagreements or conflicts that may have affected the person's situational awareness, decisions and actions?
- Was the division of tasks and responsibilities between the person concerned and other persons clear and expedient?
- Had norms and values developed in the group that enabled unfortunate practices, for example breach of procedures that had become common practice in some situations?

Factors such as inadequate follow-up by managers, an unclear division of tasks and a poor flow of information can reduce the amount of information the person bases their situational awareness on, and may therefore have a negative impact on their decisions and actions. Depending on the other circumstances in the situation, this may contribute to the occurrence of an accident.

3. Investigation of human factors, and the NSIA method

4. Investigation of human factors, and the NSIA method

In the introductory phase of the NSIA's safety investigations, work is primarily carried out to clarify the sequence of events. In this context, a mapping of human factors will usually be about gaining an overview of actions, or lack thereof, of the key parties involved, which may have had an impact on the sequence of events and the outcome of the accident.

Then, the local safety problems are identified, meaning what went wrong. Actions performed by those involved in the accident form a key part of this analysis. If an action seems to have contributed to the occurrence of an irreversible physical event, it will be natural to investigate this action in more detail. This is done based on the model in section 1.1.

Where appropriate, the NSIA performs a barrier analysis in the safety investigation. A barrier analysis maps the investigated system's established defences against accidents and undesirable incidents, and the barriers that could have been in place to prevent or limit damage or injury in the sequence of events concerned.

Based on the investigation of what went wrong in terms of human functioning, the barrier analysis will seek to find answers to the following questions:

- To what extent has the system attempted to predict the possibility of this type of human functioning, and that this, under certain conditions, could contribute to an accident occurring?
- Has the system designed and implemented barriers against this, for example in the form of technical devices or formalised procedures?
- Does the function of the barriers depend on human functioning? Where this is the case, has the system taken performance variability into account, meaning that it is normal for people to vary in how well they perform a task?[10]

The sequence of events describes WHAT happened WHEN. A sub-investigation of human factors will often provide a better understanding of WHY something happened, by investigating people's subjective understanding of the situation they found themselves in, and which led to the actions they performed (or did not perform). The analysis part of the report can also say something about how others in the same situation normally would have acted, i.e. compare actions in the sequence of events with normal, expected and ideal practice.

[10] This applies to the same individual's performance from time to time as well as to variation in how well different people perform a task.

4. Tools

5. Tools

As mentioned, the NSIA has developed an interview guide for human factors, which is based on the model presented in this document.

The NSIA also has other tools available that can be used together with our model to investigate human factors, for example tools that can be used to identify fatigue.

Conclusion

Conclusion

This thematic booklet provides a brief description of how the NSIA investigates human factors when an accident has occurred.

By answering the following three questions, we gain a better understanding of what happened and why, and which human factors can help explain why the accident happened:

1. Which of the person's decisions and actions seem to have had the greatest impact on the sequence of events?

2. What situational awareness were these decisions and actions based on?

3. What factors have or may have affected the person's situational awareness, decisions and actions?

Investigations of human functioning based on the model in section 1.1 are integrated in the NSIA's safety investigations where needed. Other models and methods are also used as required, however.

This booklet is intended as a guide for all accident investigators in all phases of the investigation where the need arises, from the preparation of interviews to writing reports.