INFORMATION PAPER

Complex decision-making

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Key messages

- Field-based personnel are often required to diagnose and respond to emerging conditions in situations that are complex, dynamic, and underspecified.
- In such situations, decision-making typically follows a *satisficing* approach, seeking a ‘good enough’ response rather than the ‘best’ response.
- Adherence to prescriptive procedural control measures is not an effective approach to risk management in complex field-based situations.
- Organisations should seek to improve the capacity of personnel in complex field-based situations to make ‘good enough’ decisions which ensure that risks will continue to be reduced to a level that is as low as reasonably practicable.

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Key definitions for this information paper

The following are some useful definitions for terms used in this information paper. They are a suggested starting point only and are not prescriptively defined, unless otherwise indicated.

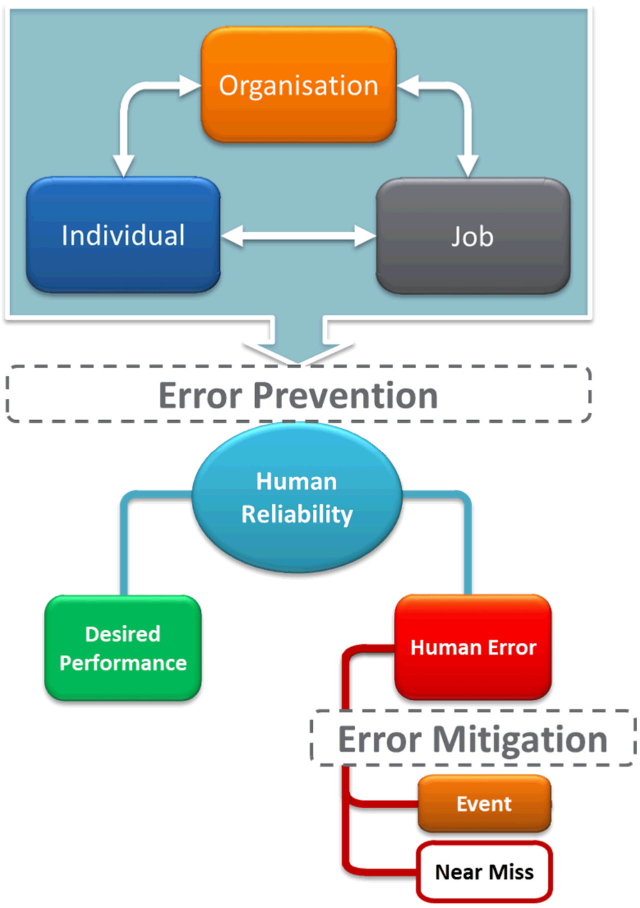
Hazardous event	*A collective term encompassing safety, integrity, and environmental incidents, used for readability purposes within this information paper.*
Hindsight bias	*Following an event, potential signals and cues are viewed as having greater significance than was apparent while they were occurring. This can lead to the belief that an event was more predictable than it actually was, and can result in an oversimplification of cause and effect.*
Human error	*Failure of a planned action to achieve a desired outcome.*
Performance-shaping factors	*Individual, job-level, or organisational variables that can influence human reliability.*
Satisficing	*Using a mental shortcut to decide on a course of action that will satisfy the minimum requirements necessary to achieve a particular goal (adapted from Simon, 1956).*

1. Introduction to the human factors information paper series

'Human Error' has long been identified as a contributing factor to incident causation. Commonly cited statistics claim that human error is responsible for anywhere between 70-100% of incidents. It seems logical, therefore, to blame incidents on individuals or small groups of people and to focus remedial actions at the individual level (e.g. training, disciplinary action, etc.). However, by taking this approach in addressing human error, organisations ignore the latent conditions in their work systems that contribute to human error across the workforce. Rather, human error should be recognised as an outcome of combined factors, instead of the root cause of an incident. Organisational, job, and individual factors all interact to influence human reliability, that is, the likelihood that an individual will perform their task effectively or make an error.

This publication forms part of a series of information papers focusing on human factors. NOPSEMA defines human factors as "the ways in which the organisation, the job, and the individual interact to influence human reliability in hazardous event causation". Reliable behaviour results in desired performance, while unreliable behaviour may result in human error, which can lead to events and near misses. This interaction is represented in Figure 1.

Figure *1 – A Model of Human Factors*



The human factors information paper series is designed to provide information about the ways in which organisational, individual, and job factors influence human reliability, and how organisations can minimise or optimise the effect of these factors, to assist in the prevention and mitigation of hazardous events and drive continuous improvement in safety, integrity and environment performance.

1.1. Intent and purpose of this information paper

Of accident and dangerous occurrences reported to NOPSEMA, procedures are the most frequently identified human performance difficulty (HPD) root cause category, accounting for roughly one third of all HPDs reported. The most frequently cited root causes of procedural control failures include:

- procedure followed incorrectly – details need improvement
- procedure wrong – situation not covered
- procedure followed incorrectly – no check-off
- procedure not used – no procedure
- procedure followed incorrectly – data wrong or incomplete.

Collectively these root causes suggest that procedures frequently lack sufficient or accurate detail and are unable to ensure effective error risk control. At the same time, permissioning documents (e.g. Safety Cases) continue to identify procedures as one of the primary control measures for minimising error risk.

Offshore petroleum activities are controlled through a web of socio-technical systems (i.e. systems that comprise human and technical components) that are:

- complex – multiple components interact with each other and the environment
- dynamic – conditions, components and their interactions are not static
- interdependent – components rely upon each other to deliver outcomes
- underspecified – a complete specification of how work should be carried out in all situations is not possible.

Facility personnel necessarily adjust their performance, acting as a ‘buffer’ between the dynamic elements of these systems to ensure they continue to function as intended. Within such systems, reliance upon rote compliance to procedural controls is insufficient to manage risk effectively. Rather, field-based personnel need to be able to accurately diagnose and respond to emerging conditions to ensure systems are functioning within acceptable parameters.

The purpose of this information paper is to describe the cognitive processes underpinning individual decision-making in complex field-based situations, and to identify strategies that may improve the quality of decision-making in such situations.

Please note: Information papers provide information, background and practices to foster continuous improvement within industry. NOPSEMA acknowledges that what is good practice, and what approaches are valid and viable, will vary according to the nature of different organisations, offshore facilities and their hazards.

2. Decision-making in complex situations

Complex situations are those in which personnel are required to diagnose and solve problems, adapt to unexpected change, and balance competing priorities, often with limited or constrained resources (e.g. information, tools and equipment, time, personnel). Complex situations on offshore petroleum facilities include drilling and well intervention activities, process upsets, production start-up, unplanned maintenance, and emerging hazardous events such as loss of well control, loss of hydrocarbon containment, or fire and explosion.

In these situations, facility personnel are expected to access their mental model of the system and its components, understand the nature of the problem, anticipate and evaluate a range of potential actions and likely consequences, and select the 'best' solution based on all of the information available to them at the time. The expectations placed upon facility personnel in such situations are often implicit, and typically fail to take into account the nature and limits of human cognition.

What do we know about human cognition?

- Humans construct mental models to understand the world and its operation.
- Mental models are created and refined through experience.
- Mental models allow individuals to make useful inferences about what is happening, what will likely happen next, and what can happen.
- Mental models are often imprecise and incomplete (i.e. "buggy").
- Human information processing capacity is limited.
- Mental shortcuts (heuristics) are used to streamline thinking processes.
- Heuristics provide substantial benefits and make it possible for humans to function in multi-stimulus environments, but they can create subconscious biases.
- Awareness of heuristics and biases does not prevent their activation.

To deliver work within complex situations, facility personnel engage in continuous internal negotiation between interacting or conflicting goals, making trade-offs between costs, values, and risks. Such trade-offs are made in the face of uncertainty, risk, and constrained resources, in the knowledge that there is no risk-free option. This process is known as the efficiency-thoroughness trade-off principle (Hollnagel, 2002).

2.1. Recognition-primed decision-making

In time-bounded field-based situations, skilled personnel engage in pattern matching to understand the problem and choose a course of action. Rather than comparing and contrasting all possible options to identify the 'best' solution, skilled personnel tend to apply a *satisficing* approach where situational cues are matched with remembered response options to find a solution that is 'good enough'.

Decision-making occurs in two stages: (1) assess the situation; (2) decide the action. Through their experience, skilled facility personnel build a mental set of situational prototypes, which they match to current situational cues to identify a course of action that is likely to succeed. A potential course of action is evaluated via mental simulation to determine (a) whether it will meet the objective and (b) whether it is likely to lead to other unacceptable consequences. If it is believed that the objective can be met without unacceptable consequences, then the action is implemented. In most situations, the first potential course of action identified meets the requirements of both criteria and so no further options are considered; otherwise the next potential course of action is evaluated against both criteria, and so on until a 'good enough' option is identified. Throughout this process, options are evaluated against the outcome criteria, not against other potential options.

When the situation does not match the prototypes contained within the decision-maker's mental model, a story-building strategy is used to mentally simulate the likely events leading to the current observable situation. The plausibility of various stories allows the decision-maker to select an interpretation that sufficiently explains the situational cues. The decision-maker is then able to categorise the situation, select a response option and evaluate it against the above described outcome criteria. The US Chemical Safety Board (2016) report into the Macondo well blowout illustrates how story-building can emerge in response to uncertain or unexpected situational cues.

Example – Story-building during the Macondo well blowout

On April 20, 2010, during temporary well abandonment activities at the Macondo oil well, control of the well was lost resulting in a blowout. The ignition, explosions, and fire led to the deaths of 11 members of the workforce, serious physical injuries to 17 others, and marine and coastal damage from a reported 4 million barrels of released hydrocarbons.

Following the installation of a cement barrier, the crew commenced negative pressure testing to assess the integrity of the cement. The crew attempted negative testing several times over a three-hour period, where trapped pressure was bled from the drillpipe only to rise again. Following a decision to change the procedure to test on the kill line, no flow was observed on the kill line for 30 minutes; however, pressure on the drillpipe remained.

"The well crew spent 80 minutes discussing the negative test results and their implications. This discussion suggests that the crew did, in fact, recognise that the well data they were examining were atypical enough to warrant further observations and consideration." (p. 70)

It appears that the well crew could not identify a situational prototype to match the observed situational cues. This resulted in the use of a story-building strategy, where the concept of a "bladder effect" was offered to explain the continued pressure on the drillpipe. This story was offered by a competent and experienced professional who was viewed as a credible and reliable source of information, and so the "bladder effect" story was accepted as the most plausible explanation for the observed situational cues. A response option, to accept the negative test and continue abandonment, was then selected based on that explanation.

Adapted from CSB (2016)

In complex field-based situations, personnel may be required to act on incomplete information, referencing imprecise mental models, while experiencing reduced cognitive capacity due to stress associated with time pressure and possible consequences of escalation. Facility personnel are susceptible to cognitive biases such as overconfidence and confirmation bias. Confirmation bias occurs when information is evaluated based on its alignment to an existing belief or decision rather than its objective rigour; once a decision is made, new information supporting the decision is accepted as robust while new information that detracts from the decision is dismissed as flawed or inconsequential.

An understanding of the cognitive processes associated with field-based decision-making can facilitate the development of strategies to improve decision outcomes and reduce potential error risk. Such strategies are discussed in the next section.

3. Risk management

Improving decision-making during complex field-based situations should not rely upon development of procedures with increased detail and prescription, or procedures that attempt to specify a greater range of potential situations. Rather, organisations should seek to build the capacity of facility personnel to make ‘good enough’ decisions in response to emerging situational cues. The following strategies may contribute to improved decision-making capability:

- Make the operational boundaries and boundaries of system performance explicit, and equip personnel with the skills to cope with processes at those boundaries.
- Provide scenario-based training and simulation to enhance the robustness and representativeness of situational prototypes and associated response options.
- Include communication and situation assessment components within training and simulation activities.
- Frame procedural controls as decision-making aides and design them accordingly. Use images, flow charts, and quick reference guides rather than wordy documents.
- Ensure training and procedure content includes how to recover control and limit escalation.
- Consider the types of information provided and methods of delivery to improve pattern-matching accuracy and de-bug mental models.
- Monitor performance variability. Variability within the system will always exist and is necessary for personnel to learn and for the system to develop. Variability should therefore be monitored to determine what is useful and what is potentially harmful.
- Consider the impact of conflicting organisational goals on what facility personnel need to achieve.

Section 4 provides a worked example illustrating how some of these strategies can be put into practice.

3.1. Learning from events

Following a hazardous event involving a complex situation, to minimise *hindsight bias* investigations should not focus on what “should” have been done or which procedures were not followed. Rather investigations should seek to understand why the actions taken at the time made sense to the facility personnel involved. This type of approach can uncover relevant *performance-shaping factors* leading to more useful learnings and corrective actions. In addition to standard scope items, investigations should also seek to answer the following questions:

- Were operational boundaries or boundaries of system performance documented, up-to-date and readily accessible?

- Were operational boundaries or boundaries of system performance approached or exceeded?
- Were cues (including alarms, instrumentation, displays) misleading, overwhelming, or otherwise unhelpful?
- Which cues were attended to, ignored, or went unnoticed?
- How were the cues interpreted?
- Were there gaps or misconceptions in facility personnel mental models?
- Were procedures outdated, ambiguous, unnecessarily bureaucratic, incorrect, inefficient, or misleading?
- Did the event emerge through normal performance variation (i.e. a common way of doing things)?

Strategies to improve field-based complex decision-making should not seek to change the cognitive processes underpinning this type of decision-making; there is no evidence to suggest that this is either possible or helpful. Rather, strategies should engage with and exploit existing cognitive processes to enhance decision-making and reduce error risk.

Further information can be found on the NOPSEMA webpage for the following related topics:

- '*Human factors in accident investigations*' information paper
- '*Critical task analysis*' information paper
- '*Human factors in engineering and design*' information paper
- '*Procedures and instructions*' information paper.

4. Worked Example – Improving operational decision-making

Hypothetical company Very Good Drilling Company, while planning a drilling campaign, identified a need to improve the decision-making capability of field-based personnel during emerging situations. They developed a range of strategies to help personnel better identify and understand operational changes, and to assist personnel in recognising when to stop the job.

Contingency plans were developed to describe the course of action to be taken in the event of specific unexpected but possible circumstances (see Oil & Gas UK, 2012).

Campaign work packs and risk assessment documents were updated to include descriptions of mandatory stop points (i.e. situations or conditions under which personnel must stop the job). These stop points were discussed at each prestart meeting, and during all operational planning discussions throughout the campaign.

Crew Resource Management training (see IOGP, 2014) was implemented across the facility to improve the effectiveness of communication between personnel.

Regular and frequent simulator training was conducted throughout the campaign, with training modules designed to simulate potential upsets and emerging conditions. The intent of the simulations was to ensure that personnel were able to accurately diagnose the situation, recover control, and limit escalation. Personnel were engaged in debrief discussions following each simulation to facilitate learning and improve decision-making. Debriefs prompted personnel to consider whether there were gaps or misconceptions in their mental models, and assisted them in revising their mental models accordingly.

Post-job debriefs were conducted to identify areas of performance variability. Open-ended questions (adapted from Hollnagel, 2014) were used to explore how personnel varied their actions in response to situational cues, targeting the three primary drivers for performance variance:

- What did personnel need to do to maintain or create good working conditions?
- What did personnel need to do to **compensate for something that was missing** (e.g. time, tools, equipment, materials, information, people)?
- What did personnel need to do to **avoid future problems** (e.g. adjusting actions to avoid interfering with other jobs, postpone a job to wait for better conditions, situations where continuing unchanged could lead to problems)?

Information collected during debriefs was used to feed into future job planning and risk assessment, with feedback provided to relevant shore-based personnel on the situational factors affecting field-based operational decision-making.

5. References, acknowledgments & notes

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