OPERATING INSTRUCTIONS IN THE PROCESS INDUSTRY: MODEL 1 or MODEL 2?

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Operating Instructions in the Process Industry:

Model 1 or Model 2?

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Abstract
A qualitative case study has been conducted about the management and use of operating instructions in a process plant in Sweden. The work was inspired by Dekker's notion of two paradigms in relation to procedures, where Model 1 is authoritarian and top-down, and Model 2 is flexible and consultative (Dekker, 2003). The results support Dekker's hypothesis, that organizations should strive towards Model 2, where "safety results from people being skilful at judging when (and when not) and how to adapt procedures to local circumstances" (Dekker, 2003, p. 235). Based on the literature review and the case study, the researcher concludes that both Model 2 theories, and some of the traditional practices associated with Model 1, are indeed valid and useful. Based on the findings, a framework was developed to illustrate potentially useful practices regarding the management and use of operating instructions in process industries.

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Contents

Operating Instructions in the Process Industry: Model 1 or Model 2?

The objective of this thesis is to get a better understanding of challenges, issues, and opportunities for improvements, related to the management and use of safety related operating instructions in the process industry. The thesis work consisted of an initial literature review, and a qualitative case study at a process plant.

The process industry, like other complex and high-risk industries, relies heavily on documented procedures for the management of operations and prevention of accidents (Mannan, 2012; Vaughen et al, 2018; Kletz & Amyotte, 2019; Hale & Borys, 2013a). At the case study plant, an internal analysis of losses of primary containment and other process safety related barrier failures found that "procedures and operator actions" was the second most common causal factor (personal communication, October 1, 2021). Deviations from procedures are frequently implicated in major accident investigations, including high-profile disasters like Piper Alpha, Texas City and Buncefield (Hopkins, 2011). Consequently, many high-risk industries are looking for ways to improve compliance with procedures (Hale & Borys, 2013a).

However, in complex activities, procedures can never specify all the considerations and actions required for safe operation (Dekker, 2003). Adaptations and improvised solutions are necessary, and violations of rules and procedures in critical situations can sometimes prevent or mitigate accidents (Dekker, 2003; Reason, 2008). Excessive proceduralization can be overwhelming to oversee and overview, and too much focus on rule-following can restrict constructive adaptation, according to several writers (e.g., Dekker, 2003; Amalberti, 2013; Hale & Borys, 2013a and 2013b; Bieder & Bourrier, 2013).

A notion of two contrasting paradigms in relation to procedures and safety, Model 1 and Model 2, was introduced by Sidney Dekker (2003). In short, Model 1 can be described as authoritarian and top-down, based on an excessive belief in rules and procedures as a basis for safety. In contrast, Model 2 is flexible and consultative, based on the view that interpretation and adaptation is necessary since procedures can seldom fully specify all the suitable actions in a complex work situation. Hence, Dekker and others (e.g., Hale and Borys, 2013 a and b; Hendricks and Peres, 2021) suggest that most organisations should move towards Model 2, to increase the utility of procedures and make progress on safety.

The development and use of operating instructions in the process industry has not been studied in relation to Model 1 and Model 2 theories, at least not by rigorous research. A lack of empirical testing of theoretical models and concepts in practice can restrict progress in safety science, and a lack of knowledge about safety science among practitioners can lead to ineffective safety programs in industry (Rae et al, 2020; Shorrock, 2019). Hence, this thesis is warranted and could be potentially useful for both practitioners and theorists.

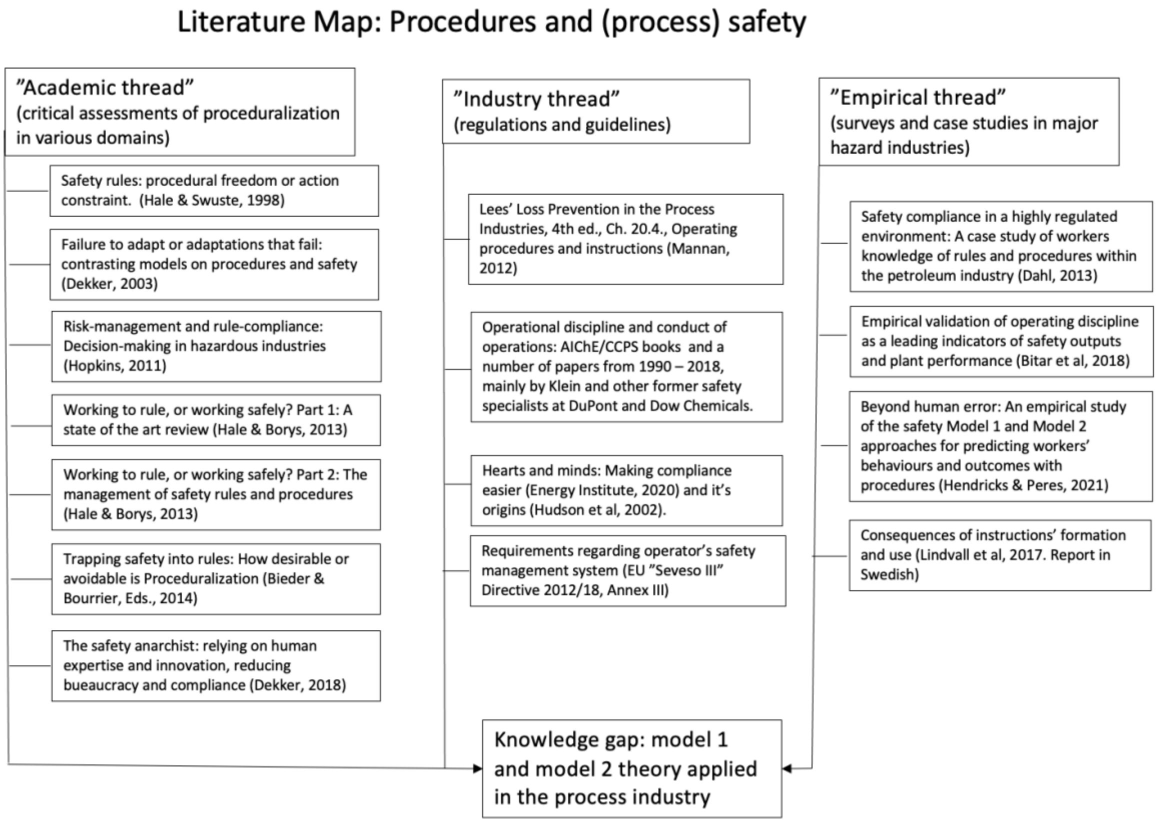
Literature review

A brief conceptual literature review (Thomas & Hodges, 2013) was conducted during the development of the proposal for this thesis. The researcher was already aware of a very useful report about the design and use of instructions, written by consultants for the Swedish Radiation Safety Authority (Lindvall et al, 2017). Seemingly useful titles in the reference list were downloaded via the Lund University library search engine LUBsearch and the Scopus scientific literature database and skimmed. Two papers by Hale and Borys (2013a and b), "Working to rule, or working safely? Part 1: A state of the art review", and "Working to rule, or working safely? Part 2: The management of safety rules and procedures", were found to be particularly comprehensive and relevant for the emerging thesis topic. Again, the reference lists were used to identify and skim additional literature, including the original paper about Model 1 and Model 2 (Dekker, 2003). To identify more recent literature, Scopus was used to list literature that cites the three papers mentioned. Again, the researcher skimmed titles, abstracts, and papers, to identify and review the most useful ones. This type of iterative process was continued on and off during the duration of the thesis work. In addition, the key word "operational discipline" was used to download some papers about a concept, which the researcher had prior knowledge about. The following prioritisation list was developed to focus on the most useful literature.

1. Articles directly connected to the thesis topic, in the most relevant peer reviewed journals (e.g., Safety Science, Applied Ergonomics, Process Safety Progress, Journal of Loss Prevention in the Process Industries).
2. Books, directly or partly connected to the thesis topic.
3. Non-peer reviewed sources, publications by research institutes, professional associations, conference organizers etc, directly connected.
4. Previous Human Factors and System Safety theses directly or partly connected.

Figure 1

Overview of the most useful literature found (inspired by Cresswell & Cresswell, 2018).



A debated subject

A procedure can be defined as a "specified way to carry out an activity or process" (Hale & Borys, 2013a, p. 208, citing OHSAS 18002:2008). Procedures, rules, instructions, guidelines, and similar documents, can be divided into three categories (Hale & Swuste, 1998):

- Performance goals describe what is to be achieved
- Process rules describe broadly how a set of tasks should be approached, e.g., requirements to make a formal risk assessment or consult with defined people when certain situations arise
- Action rules describe step-by-step how to conduct a particular task, i.e., specifically what to do in each situation

An operating instruction, which is the focus of this thesis, is typically a set of action rules that describe how various operator tasks should be performed.

There is an on-going debate among safety scientists, about merits and problems related to procedures and rules:

> There is no doubt that proceduralization and documented activities have in the past brought constant progress, avoided recurrent mistakes, and allowed for 'best' practice to be adopted. Yet it seems that the exclusive and intensive use of procedures today is in fact a threat to progress in safety. (Bieder & Bourrier, 2014, p.3)

In short, the main threat is described as an ever-increasing number of rules and procedures, often written, and issued by people who don't fully understand the work that they try to control, as well as strict compliance requirements, and calls for accountability when something goes wrong. As a result, the people who do the actual work are restricted from using and developing their expertise (Bieder & Bourrier, 2014).

In the following, some background about human error, adaptation, and drift is presented, before proceeding to arguments for procedures, and the problematic aspects, respectively. Following that, we turn to Model 1 and Model 2, and a possible compromise between the two.

Human error

Historically, human error has often been used to explain accidents, but it is a concept that has become debated in modern safety science (Woods et al, 2010). It is defined by James Reason as "the failure of planned actions to achieve their desired ends - without the intervention of some unforeseeable event" (Reason, 1997, p. 71).

In the 1990 book, 'Human error', James Reason first described a much-referenced human error taxonomy, inspired by Rasmussen's skill-rule-knowledge framework (Reason, 1990). These quotes from Reason's 1997 book, 'Managing the Risks of organizational Accidents' briefly explain the framework and the taxonomy:

> At the skill-based (SB) level, we carry out routine, highly-practised tasks in a largely automatic fashion with occasional conscious checks on progress. This is what people are very good at most of the time.
>
> We switch to the rule-based (RB) level when we notice a need to modify our largely preprogrammed behaviour...This problem is likely to be one that we have encountered before, or have been trained to deal with, or which is covered by the procedures.
>
> The knowledge-based (KB) level is something we come to very reluctantly. Only when we have repeatedly failed to find some pre-existing solution do we resort to the slow and effortful business of thinking things through on the spot. (Reason, 1997, p.70)

In the taxonomy, skill-based errors, where actions unintendedly deviate from the plan, are called slips or lapses:

> Slips relate to observable actions and are commonly associated with attentional or perceptual failures. Lapses are more internal events and generally involve failures of memory. (Reason, 1997, p. 71)

Rule-based and knowledge-based errors, where actions follow the plan, but the plan is inadequate, are called mistakes:

> Here, the failure lies at a higher level - with the mental processes involved in assessing the available information, planning, formulating intentions, and judging the likely consequences of the planned actions...Rule-based mistakes involve either the misapplication of normally good rules, the application of bad rules, or the failure to apply a good rule (a violation). Knowledge-based mistakes occur when we have run out of prepackaged solutions and have to think out problem solutions on line. This, as discussed above, is a highly error-prone business. (Reason, 1997, p. 71)

Reason points out that in complex hazardous industries, the variety and numbers of possible errors can be very high. Hence, while operating instructions and checklists can be helpful and reduce the likelihood or consequence of some errors, "wholly safe behaviour can never be controlled by feedforward prescriptions" (e.g., procedures) (Reason, 1997, p. 74).

Deliberate deviations from rules and procedures ('violations') do not necessarily lead to serious accidents since most people are sensible and try to avoid causing serious accidents. However, violations can cause accidents when combined with errors, since violations often erode safety margins (Reason, 1997). Hale and Borys summarized several factors that can lead to violations, based on a comprehensive literature review (Hale & Borys, 2013, p. 212):

Attitudes to and habits of non-compliance

Design/layout making violation necessary to achieve objectives

Management turns a blind eye or is inconsistent in sanctioning

Conflicting demands, pressure towards productivity

Workload and work pressure

According to Sidney Dekker (2014a), typical "Old Views" are that human error is the dominant cause of accidents, and that rules and procedures can control human behaviour. The "New View", in contrast, is that safety is continuously created by people at 'the sharp end' (e.g., plant operators), by interpretations and adaptations in the phase of uncertainties, goal conflicts and resource constraints (Dekker, 2014a). Hence, "human errors" should be viewed as "adaptations that fail", a starting point for discussion about local rationality, technology, and deeper organizational factors (Woods et al, 2010).

Adaptation and drift

In complex systems, rules and procedures can't specify all the actions and behaviours that are necessary for safe operation. Hence, interpretation and adaptation by the people involved in the primary activities of an organization ("the sharp end') is in fact necessary for successful operation (Woods, 2015; Bergström et al, 2015; Provan et al, 2020). Erik Hollnagel uses the terms 'Work-As-Done' and 'Work-As-Imagined' to illustrate (Hollnagel, 2014, p. 40-41):

> At the sharp end we find the people who actually must interact with the potentially hazardous processes...pilots, physicians, or power plant operators...everyone at the sharp end knows that it is only possible to work by continually adjusting what they do to the situation...'Work-As-Done'
>
> The blunt end is made up of the many layers of the organisation that do not directly participate in what is done at the sharp end...Here there is a tendency to emphasise work as it *should* be done (called 'Work-As-Imagined').
>
> When seen from the (traditional) sharp end it is obvious that Work-As-Done is, and must be, different from Work-As-Imagined, simply because it is impossible for those at the blunt end to anticipate all the possible conditions that can exist.

However, adaptation can also lead to dangerous errors, and drift towards failure. Rasmussen's much referenced "model of boundaries" (Rasmussen, 1997; Le Coze, 2015) is illustrative. As shown in the figure below, it illustrates how people will use their degrees of freedom to find an optimum performance by experimentation and adaptation within three boundaries: Economic failure, unacceptable workload, and unacceptable performance. Management's pressure towards efficiency, and employee's resistance against unacceptable workload, can push the system towards unacceptable risks. In the model, Rasmussen points at safety culture as the counterforce away from unacceptable performance. Adherence to safety related procedures would also be an applicable counterforce, according to the researcher. If such counterforces are not strong enough, an accident is likely to occur.

Figure 2

Rasmussen's model of boundaries (reprinted from Rasmussen, 1997, p. 190)

190 *J. Rasmussen*

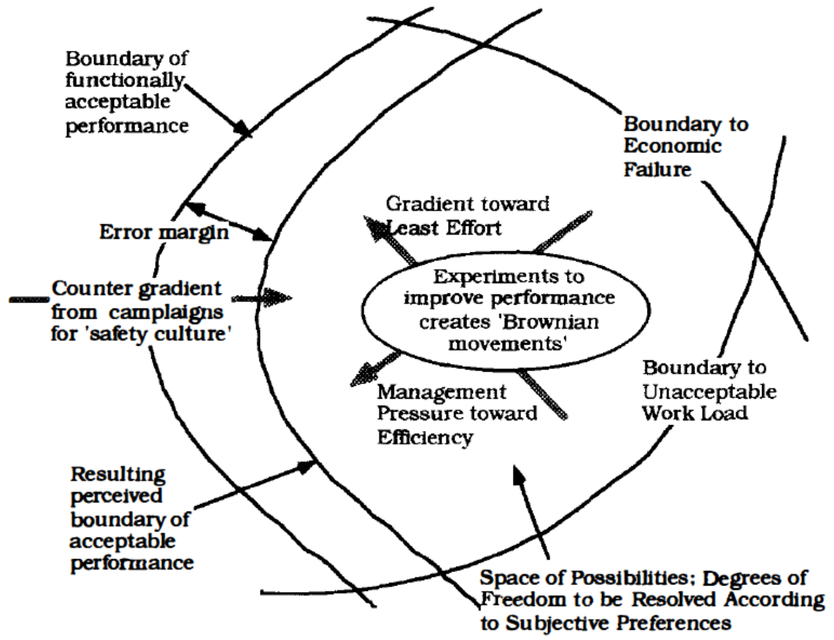


Fig. 3. Under the presence of strong gradients behaviour will very likely migrate toward the boundary of acceptable performance.

In a study about an accidental shoot-down of friendly helicopters, where safety critical procedures had eroded over time, Scott Snook uses the term 'practical drift': "It is this structural tendency for subunits to drift away from globally synchronized rule-based logics of action toward locally determined task-based procedures that places complex organizations at risk" (Snook, 2002, p.12). Some of the lessons from the space shuttle disasters, Challenger and Columbia, also point at the problem with drift: "People are almost certain to reduce some safety factors after creating a system, and successful experiences make safety factors look more and more wasteful" (Starbuck and Milliken, 1988, p.333) and "What makes safety/production tradeoffs so insidious is that evidence of risks become invisible to people working hard to produce under pressure so that safety margins erode over time" (Woods, 2005).

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Why procedures?

According to Reason, rules and procedures are indeed needed for safe operation of complex systems: "Not only are such rules important for guiding safe behaviour in relation to identified and understood hazards, they also constitute an important record of the organization's learning about it's operational dangers" (Reason, 1997, p. 75). The main reasons for standardized and documented procedures are (Reason, 1997; Hale & Borys, 2013a):

Tasks can be complicated and difficult to remember

Different actors need coordination

A reference for training and monitoring

As a form of 'organizational memory'

Furthermore, in complex and hazardous industries, such as process plants, the boundary between safe and unsafe conditions can sometimes be difficult to recognize for operators, as pointed out by Hopkins (2011, p. 112):

> Engineers may have done complex calculations to identify the operating risks and to determine a safe operating envelope, that is, a set of temperature, pressure, flow and other limits that ned to be observed if a process is to be carried out safely. Frontline operators cannot be expected to appreciate the full significance of these limits and must simply regard them as rules governing the operation of the plant. In short, safety depends on operators complying with a set of operating rules which themselves are derived from a complex technical risk-assessment.

Hopkins also points at the need for rules and compliance to mitigate potential "risk-taking behaviour by workers, such as: a desire to make life easier for oneself, pressure to get the work done, and a preference for working skilfully, which may mean 'closer to the edge' ".

In a recent article, Nancy Leveson also points at the need for procedures, as well as adaptation and interpretation (Leveson, 2020, p. 98):

> There are many instances, however, when procedures are useful and compliance important...Pilots, for example, cannot be expected to be experts on and understand everything about the design of the aircraft...If the procedures don't work, that does not mean that we should not train the pilots on procedures and when it's appropriate to apply those procedures.

The Systems Theoretic Accident Model and Process (STAMP), developed by Leveson, has been the most frequently cited systemic accident model (Underwood & Waterson, 2014). It is centred around a "general sociotechnical system hierarchical safety control structure" (Leveson, 2011), showing relationships between components, people, functions, and subsystems in a hierarchy, as well as the relevant controls required for the prevention of accidents. At the operational level, both feedforward controls (e.g., risk assessments, operating and maintenance instructions etc) and feedback controls (e.g., incident reports, audit reports etc) are included. The model also points at the need for revised operating procedures when engineering parameters change due to plant modifications or maintenance findings.

Can procedures be problematic?

The sections above have already alluded to several problematic aspects in relation to procedures. A quote by the late Trevor Kletz illustrates a practical double-bind: In complex activities such as process plant operations, there are so many components, variables, and interactions. Hence, "we cannot cover every possibility in our instructions and the longer we make them, the less likely they will be read." (Kletz & Amyotte, 2019).

On a wider scale, in large organisations generally, there is an ever-increasing number of rules, instructions and procedures, especially in high-risk domains such as process industries, transportation, nuclear energy and health care (e.g., Leveson, 2011; Hale & Borys, 2013a and 2013b; Bieder & Bourrier, 2013; Shorrock, 2017; Dekker, 2014b; Dekker, 2020). For example, incident investigations and audit reports often result in new or extended rules and procedures.

Furthermore, increasing proceduralization is driven by global trends such as regulatory requirements, corporate bureaucratization, certified management systems, and demands for compliance and accountability (Hale & Borys, 2013a; Dekker 2014b/2020).

As a result, the willingness, opportunities, and capability to adapt to increasingly complex interactions, changing environments, and abnormal situations (i.e., resilience) can be impaired, as people become too accustomed to follow rules and procedures instead of developing skills and tacit knowledge, or become afraid of being held accountable for violations (Bergström et al, 2009; Dekker, 2014b; Dekker, 2020; Besnard&Hollnagel, 2014).

Amalberti (2014) makes a distinction between three very different models of safety: Resilience, HRO (High Reliability Organizations) and Ultra-safe. The latter includes the nuclear and civil aviation industries, who invest in and use procedures to an extreme degree. The process industry belongs to the HRO model, where procedures are also important but there is more reliance on operator expertise and adaptation. According to Amalberti, in the absence of major accidents or regulatory pressure, it is very difficult for an organization to change model. It may be that HRO's generally don't have the capacity to develop the procedural and training systems required in the ultra-safe model, e.g., due to culture, limited human resources, and economic constraints.

Model 1 and Model 2

Sidney Dekker (2014b) is generally critical of bureaucratization, proceduralization and responsibilisation, but he also seems to recognize that procedures can be useful. He posits that there are in fact two different paradigms. Model 1 can be described as rule-following, where "procedures represent the best thought-out, and thus the safest way to carry out a job" (Dekker, 2003, p. 233). It is a traditional Tayloristic approach, where engineers and managers write rules and procedures that workers are requested to follow. This approach can in fact produce good safety results, especially in terms of the more common workplace accident risks, such as slips, trips, and falls (Hopkins, 2011). In contrast, Model 2 views procedures as "resources for actions" and posits that "safety results from people being skilful at judging when (and when not) and how to adapt procedures to local circumstances" (Dekker, 2003, p. 235). Some risks, especially in complex activities, are difficult or even impossible to control without moving towards Model 2, according to Dekker. Additional characteristics of the two models are shown in Table 1 below.

Table 1

Two paradigms in relation to procedures, Model 1 and Model 2 (Dekker, 2003, p 233 and 236)

Model 1	Model 2
Procedures represent the best thought-out, and thus the safest way to carry out a job.	Procedures are resources for action. Procedures do not specify all circumstances to which they apply. Procedures cannot dictate their own application. Procedures can, in themselves, not guarantee safety.
Procedure-following is mostly simple IF-THEN rule-based mental activity: IF this situation occurs, THEN this algorithm (e.g., checklist) applies.	Applying procedures successfully across situations can be a substantive and skilful cognitive activity.
Safety results from people following procedures.	Safety results from people being skilful at judging when (and when not) to adapt procedures to local circumstances.
For progress on safety, organizations must invest in people's knowledge of procedures and ensure that procedures are followed.	For progress on safety, organizations must monitor the gap between procedures and practice. Additionally, organizations must develop ways that support people's skill at judging when and how to adapt.

A framework for rule management

Hale and Borys (2013b) have proposed a framework to enable organisations in high-risk domains to improve their "rule management" towards Model 2, while keeping useful practices that may have existed under Model 1, such as organizational memory, attention to detail, deference to technical expertise when required, and compliance when agreed rules and procedures are applicable. Rules, in this context, include instructions, procedures and similar documents. The following steps are described as "options" within the framework (Hale & Borys, 2013b, p. 229):

1. Monitor and analyze violations as a participative activity, in order to understand them.
2. Audit violation potential.
3. Redesign the job or equipment to remove the need for procedures or violations, or to support procedure use.
4. Rewrite procedures with a well-designed process and to relevant criteria.
5. Involve/consult/inform the workforce during the rewriting.
6. Train and retrain in risk perception, the procedure and its use and adaptation.
7. Anticipate the need for, and provide the authority and a system for, varying procedures.
8. Promote a learning and sharing culture around compliance.
9. Enforce, where the procedure is the agreed and appropriate best way of proceeding.

This framework has inspired the researcher to develop an alternative framework, presented and discussed in the discussion chapter.

Empirical work in the process industry

Some interesting literature about empirical work related to procedures and safety in the process industry were found.

Access to and knowledge about rules and procedures

Dahl (2013) interviewed contractors and subcontractors in the Norwegian oil industry about knowledge of rules and procedures. The workers regularly had to certify that they had the proper knowledge about rules and procedures for signing work permits, but the actual knowledge was found to vary considerably. Notably, most of the applicable rules and procedures were available only via the computerized safety management system at the company they worked for at the time. Difficulties to access the computer system, lack of training in how to use it and poor user friendliness were common. One worker made the following comment: 'You do like everybody else, and I have never seen anyone else working with the safety management system'. Other factors found to correlate with poor knowledge of the rules and procedures were routinized work, low perceived risk levels and subcontracting, as well as leadership influence and co-worker influence. The study indicates that a more rigorous and proactive approach by the oil company would be necessary to ensure proper knowledge about the applicable rules and procedures among contractors and subcontractors. One can suspect that there is some correlation between knowledge of rules and procedures on one hand, and compliance and actual safety on the other hand. However, that question was outside the scope of this study.

Model 2 supported by survey in process industries

Hendricks and Peres (2021) conducted a survey (questionnaire) of perceptions about procedures, behaviour, and safety outcome among 174 workers, mainly in the chemical and process industry in Canada and the US. Questions related to predictor variables such as attitudes towards and perceptions about procedures, and outcome variables, such as "How many incidents have you been involved in during your career?" and "How often do you deviate from procedures for a highly hazardous task?" (Hendricks & Peres, 2021, p. 4). The predictor variables were classified as either "individual variables", e.g. "To what extent do you agree that procedures are important for your job", or "system variables" related to the quality of procedures, e.g. "How often have you found conflicting information in procedures?". Multiple regression analysis was used to assess correlations between predictor and outcome variables. The strongest correlations with outcome variables were found for perceived quality of procedures, i.e., "the better the quality, the fewer deviations, the more they used procedures, and the fewer incidents and near-misses per year" (Hendricks & Peres, 2021, p. 7). Furthermore, attitudes toward procedure utility (perceived usefulness) showed strong correlations with the outcome variables. According to the author's, the results provide support for Dekker's Model 2. S

Survey research and statistical analysis has limitations, as discussed in the method section of this thesis. Hence, the findings by Hendricks and Peres (2021) should not be taken as absolute truths, but used as inspiration for further research, perhaps using qualitative methods such as in-depth interviews or focus groups.

Operational discipline

The American Centre for Chemical Process Safety promote "Operational Discipline" (OD), a term that was introduced by process safety practitioners in DuPont in the late 1980's (Vaughen et al, 2018). A key element in OD is, "practice consistent with procedures", meaning that: (Bitar et al, 2017, p. 149)

> Procedures are documented and readily available for all appropriate SHE activities.
>
> Clear expectations exist for following procedures and for not taking shortcuts.
>
> Procedures are periodically reviewed and authorised to keep them current, including employee participation.
>
> All changes, tests, and deviations are reviewed and authorised before use.

> Training and field audits are conducted to ensure procedures are understood and followed.

The term SHE (Safety, Health and Environment) above might be misleading. It seems likely that the practices are meant to apply to all operational procedures. The word "discipline" could seem antithetical to "the New View of Safety" (Dekker, 2014a), but in its current form, OD seems not too different in principle from the Hale and Borys approach described above.

Bitar et al (2017) conducted a survey about perceptions in relation to OD principles among employees and contractors working in 'upstream oil and gas' (exploration and production) on- and off-shore in several countries. 5533 people completed the survey. Furthermore, they collected statistics about personal injuries as well as process safety incidents (losses of primary containment). A strong correlation was found between perceptions about OD implementation and process safety events and plant reliability and efficiency, but no correlation with personal injuries. They posit the following hypothesis (Bitar et al, 2017, p. 152):

> Activities leading to personal injuries, e.g., working at height, digging, moving or dropping objects tend to be simpler compared to plant start-up or equipment maintenance processes requiring many complex, rigorously followed steps. Furthermore, process safety activities may involve multiple professionals co-verifying their actions and decisions.

Several limitations of the study are discussed in the paper, including the validity of the OD measure. However, the work appears credible to this researcher, and the findings support a balanced Model 1 and Model 2 approach, as proposed by Hale and Borys.

Conclusions from the literature review

This brief literature review has demonstrated some common problems related to procedures in safety critical domains. A potentially useful approach has been proposed to reduce such problems, e.g., "...a significant culture-shift, perspective change or paradigm shift for many of those individuals and organisations operating under a pure Model 1, to accommodate the ideas of the flexibility implied in Model 2" (Hale and Borys, 2013b, p. 229). There seems to be little empirical research done about the practical use of Model 1 and Model 2 theories, at least in the process industry. Hence, this thesis seems relevant and potentially useful.

Research questions

Based on the literature review, the general thesis objective was narrowed down to the following specific research questions:

- Can the theories about Model 1 and Model 2 be considered useful in the practical management and use of operating instructions in a process plant?
- What strengths and weaknesses can be identified in relation to application of Model 2 in a process plant?

Research methodology and methods

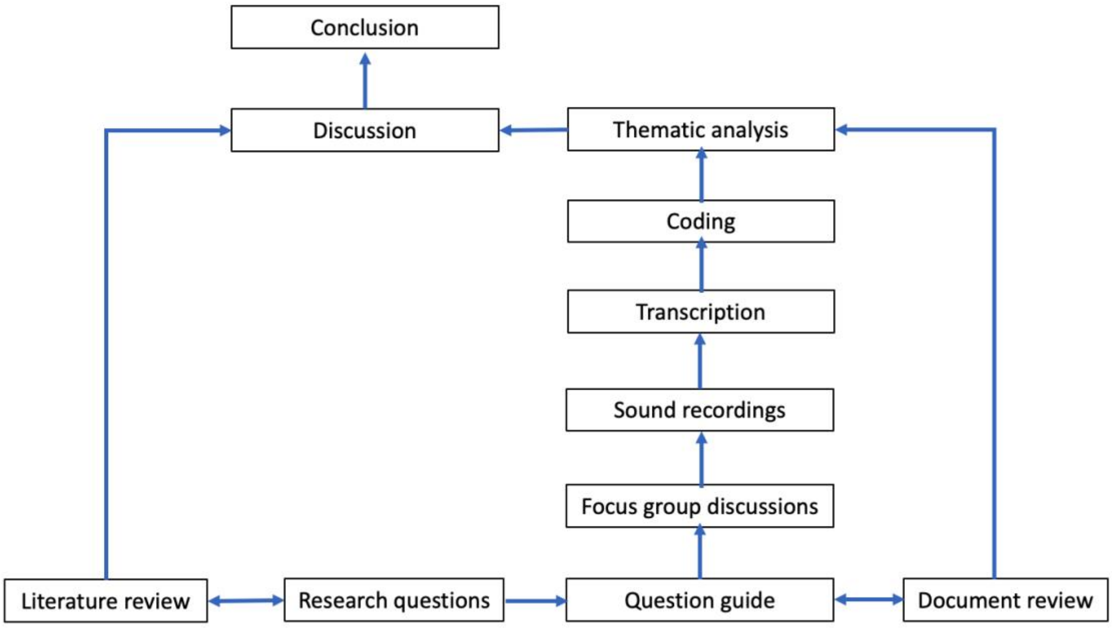
Quantitative methods are often used in safety research and social research in general. They can be useful, but there are limitations due to the focus on norms, rules and transparency which encourage a positivist world view, i.e., a belief in absolute truths (Seale et al, 2011; Blaxter et al, 2010; Crotty, 1998). Furthermore, there are various potential sources of error in survey research and statistical analysis (Brenner, 2020). In contrast, qualitative methodologies, based on constructionism and interpretivism, are also common in modern social research (Ritchie et al, 2014). Methods such as in-depth interviews and focus group discussions can provide a deeper understanding of psychological and social factors, which are important in safety research.

This thesis topic involves many human factors aspects, including culture, individual and group psychology, and social interaction between the people writing, approving, and using (or not using) operating instructions. Hence, a case study, using a qualitative research methodology with an interpretivist perspective, was considered most useful for this project.

The main research data was gathered through focus group discussions with people who are involved in writing, updating, and using operating instructions at a process plant. The subsequent thematic analysis, together with the literature review, enabled the researcher to make some conclusions about the practical utility of Model 1 and Model 2 theories. An overview of the analytic process is shown in the figure below.

Figure 3

Overview of the analytic process



The case

The plant is in Sweden. The site consists of several highly integrated process units, tank farms and a harbour, divided into three areas of operation. Large quantities of flammable liquids and gases are processed, at elevated temperatures and pressures. The plant operates continuously. There are five shifts, with about 50 operators on each, and about 600 employees altogether. Each area has an operations manager and 3-4 operations engineers. Each shift has a shift manager and 3 area shift managers, and deputies. There are about 1400 operating instructions, and an additional 1200 checklists for operator tasks, managed and published in a computer-based document management system (SharePoint application).

Document review

To prepare for the focus group discussions, and as a form of triangulation, i.e., to cross-check what was said by the informants, some pertinent company documents were obtained and reviewed by the researcher (personal communication, July 1, 2021). No specific method for document analysis was considered necessary. Company representatives assisted in selecting relevant document samples. The types and number of documents reviewed were (number of documents in brackets):

- Instructions for process unit start-up (3)
- Instruction for furnace mode change (1)
- Instructions for emergencies and abnormal situations (3)
- Work permit procedure (1)
- Incident investigations (3)
- Process safety event statistics (1)
- Safety climate questionnaire results (1)
- Guideline for writing operating instructions (1)
- Template for operating instructions (1)

A non-disclosure agreement was signed by the researcher, which prohibits sharing details of any documents supplied by the company.

Focus group discussions

Focus group discussions is a common qualitative research method, which was considered more useful for this project than individual interviews, due to the stimulation provided by group interaction. This view was inspired by Ritchie et al (2014):

> Group discussions (or focus groups - we use the term interchangeably) offer less opportunity for the detailed generation of individual accounts. They are used where the group process - the interaction between participants - will itself illuminate the research issue...This can be particularly useful in attitudinal research. Explaining or accounting for attitudes is sometimes easier for people when they hear different attitudes, or nuances on

> their own, described by other people...The interaction between participants is also useful if what is required is creative thinking, solutions and strategies. (p. 56)

A two-hour long meeting was held with each of four groups, during September-October 2021. The meetings were held in conference rooms at the plant, with the researcher and the informants participating physically. The meetings were sound recorded.

The researcher felt that the informants would feel more secure and speak more openly in smaller and more homogenous groups. Hence, there were three groups with operators only from each of the plant areas, then one group with engineers and managers. A company representative assisted in selecting the informants, based on a mixture of purposive and convenience sampling (Ritchie et al, 2014), and organize the meetings.

Table 2

Basic information about the people in each group

Group 1 Shift operators Area 1	Group 2 Shift operators Area 2	Group 3 Shift operators Area 3	Group 4 1 area operations manager, 1 refinery shift manager, 2 area shift managers, 3 operations engineers
4 persons (1 female, 3 males). Average 15 years with the company (range 2-38 years)	6 persons (all male). Average 16 years with the company (range 6-39 years)	6 persons (2 females, 4 males), Average 8 years with the company (range 2-20 years)	9 persons (1 female, 8 males). Average 24 years with the company (range 15-38)

Question guide

A set of questions was prepared before the meetings, inspired by the preliminary literature review. The actual use of the questions was flexible and adapted to the flow of discussion in each meeting. Hence, some questions were not spelled out exactly as listed, but covered indirectly, and several follow-up questions came-up during the meetings. Key questions discussed during meetings were:

1. When and how do operators use operating instructions?
2. What are the advantages of, and problems with, operating instructions?
3. When and how can deviation from operating instructions occur?
4. Are operators blamed or disciplined for not following operating instructions?
5. Who is involved in the writing and updating of operating instructions?
6. What are the problems in relation to writing and updating of operating instructions?
7. What do you think about the document system and the template for operating instructions?

Review meeting

A review meeting was held in November 2021, to get feed-back and clarify any potential misinterpretations. One engineer and four operators participated. The meeting started with a brief presentation of an early version of the thematic analysis. The informants had no objections, only comments that confirmed or reinforced the researcher's findings. The sound recordings were not transcribed or analysed, therefore.

Thematic analysis

A form of thematic analysis, a common method for qualitative analysis, was used (Braun&Clarke, 2006). First, the sound recordings from each meeting were transcribed manually by the researcher. The transcripts were reviewed several times, and useful quotes were marked with codes, i.e., a few words to capture the topic or meaning of each quote. When similar topics or meanings were found in different parts of the transcripts, the same code was reused. There were 33 codes in total, a few with sub-codes added during the analysis.

The codes and the most useful quotes were then copied and pasted from the transcripts into an excel sheet, with one row for each code and the connected quotes in one column for each meeting. Codes that where somehow related were grouped together, to form a set of themes. The quotes that were considered most indicative towards each theme were pasted into this document. The researcher then summarized his interpretation of the data for each theme. The development of codes and themes was thus an inductive approach ('ground-up') (Braun & Clarke, 2006; Ritchie et al, 2014). Based on the thematic analysis and the literature survey, a generic framework for the management and use of operating instructions was then developed abductively (Ritchie et al, 2014).

Quality aspects

The quality of the thesis was assured mainly by the intermittent discussions between the researcher and his supervisor at Lund University, and comments by the supervisor and the examiner, from the development of the thesis proposal through to the final version of the report.

Any qualitative case study can have certain limitations in terms of generalisability, reliability, and validity (Ritchie et al, 2014). The inferential generalisation may be limited, i.e., the situation at the case study plant could probably differ considerably compared with other process plants. This must be kept in mind when presenting the results and conclusions.

Reliability (replicability) and validity (extent that informants' meanings have been captured and interpreted fairly) can be problematic in qualitative research. It should be possible in theory to repeat this study by following the method description, with a different researcher and different informants. However, researcher bias, semi-structured questions, strong views among some informants, and group dynamics could affect the results and conclusions.

In this case, the range of informants was considered sufficient in terms of representational generalisation, i.e., the data is probably representative of the wider organisation. Having three groups of operators and one group of engineers and managers, and the document review, provided means of validation through triangulation.

The researcher is a chemical engineer and a process safety specialist, who worked for about 25 years at a plant similar to the case study plant. He has also been involved with the case study plant to a lesser degree. This background was helpful in the communication with the informants, but also a potential source of bias. The researcher's views in relation to the thesis topic, before the work started, can be summarized as:

- Operating instructions are essential for safety
- Adaptations are often necessary but casual and unmotivated deviations are hazardous
- Open dialogue and cooperation between operators, engineers and managers is essential

These potential biases were kept in mind during the thesis work, and mitigated by trying to keep an open mind, focussing on the data and the learnings from the literature review, and following the research process as described above. Critical questions and dialogue with the supervisor were very important in this respect.

Ethical considerations

A consent form was signed by all informants. The sound recordings and the transcriptions are confidential, used and stored only by the researcher. The names of informants are not mentioned in the report, and who said what is not disclosed to anyone outside the meetings. All informants will be invited to comment on the draft report.

Results and analysis

Document review

The type of documents reviewed have been mentioned in the methods section. Reading them was useful when preparing for the focus group meetings, and for triangulation during the meetings and the analysis. Four documents that are considered particularly illustrative for the results and analysis are mentioned here.

Procedure writing guideline

The procedure writing guideline was approved by the refinery production manager in October 2020, as a way of formalising developments during the recent migration to the new document system, as well as pre-existing practices. It is fairly short, just over three pages. The following comments can be made in relation to who is involved:

- The issuer (person writing or updating) can be either an operator, a shift area manager, a shift manager, or an operations engineer.
- Before approval, new or revised instructions shall be reviewed by another person, either a shift area manager, a shift manager, or an operations engineer.
- An operators' safety representative shall review, "when possible".
- The area operations manager shall approve all new or revised instructions before they are released.

In relation to format and style, the following is stated:

- Instructions shall be short and clear
- Use of visual illustrations is recommended
- It should be assumed that users are familiar with affected systems and equipment
- Applicable preconditions shall be stated upfront
- Specific hazards shall be pointed out

Templates for different types of instructions are attached to the guideline. Comments about the guideline and the template are made when discussing a specific instruction below, and in the thematic analysis.

Investigation of a furnace fire

During a mode change, temperatures inside a fired heater (furnace) increased above the safe operating window for several hours. High temperature alarms were indicated in the control room, but not acted upon. As a result, a tube where process media is heated inside the furnace, ruptured. Flammable fluid from the ruptured tube ignited and burned uncontrolled inside the furnace. At that point, alarm indications were observed, and control room operators shut down fuel gas and process flow to the furnace, in accordance with the applicable emergency procedure. Nobody was injured, but the furnace was badly damaged, causing costly production losses for several months.

The investigation is quite substantial (47 pages incl. appendices) and technical. A few brief quotes that relate to procedures and human error are included here:

> Operating instruction (ID no. withheld by researcher) describes operating variables and the safe operating window and points out that the heater status should be checked if any variable deviates. Hence, the panel operator ought to have identified the risks due to the high temperature and acted accordingly.

> It was process adjustments made by the control room operator during the afternoon shift and the night shift that led to the operation outside the allowed operating window. It was also a lack of attention and cooperation by the operator and other involved personnel that led to the lack of correct response to incoming alarms.

The two statements above, taken out of context, are indicative of counterfactual reasoning, which is a classic fallacy in accident investigations (Dekker, 2014a). However, the investigation as a whole is more nuanced:

> At the same time as those alarms came in, furnace X (another furnace, comment by researcher), was being shut down, which probably generated a lot of alarms, taking attention away from furnace Y (where the tube rupture occurred later, comment by researcher).
>
> Operation outside the safe operating window was allowed by the current technical design because of too much trust in the protection offered by alarms in critical situations...It is fair to question why the need for a technical barrier had not been identified and installed following hazard and operability studies over the years.

The investigation report includes a total of 9 approved recommendations. Four of them are directly human factors related:

1. Improve the training in furnace operation and furnace safety.
2. Update the operating instruction and clarify the steps for shifting from two furnaces in service to one, in relation to temperature and flow increases, with reference to the operating window.
3. Review alarm system priorities for deviations outside safe operating windows.
4. Operator mistake to be handled in a dialogue between the responsible manager and the persons involved.

The last statement, taken out of context, could be indicative of blaming and holding individuals accountable in a negative sense. The nature of the dialogue was not pursued by the researcher, but as mentioned, the report as a whole is more nuanced.

Instruction for furnace mode change

The instruction referred to in the incident investigation describes the procedure for changing from one furnace in service to the other (there are two identical furnaces that can be operated either in parallel or one at a time). At the time of the incident, both furnaces had been operating in parallel, and one was being shut down for maintenance. There was no instruction for that, therefore applicable parts of the instruction for switching furnaces were used. The potential problems with that were not discussed in the investigation report but covered implicitly as indicated by the approved recommendation to update the instruction. The copy of that updated instruction, dated April 2021, still does not seem to cover changes from two furnaces in operation to one. This was discussed with operators in Group 2. It might be indicative of the difficulty to cover every foreseeable situation and operation by instructions (and/or problems with the implementation and tracking of recommendations from incident investigations).

The updated instruction is written in the template mentioned above. Some observations by the researcher, regarding format and style:

There are 8 pages in total (the table of contents says 12 pages, reason unknown). On the first 1 1/2 page there is document information (including date of issue, names of issuer, reviewer and the approving manage etc), a table of content and some very general and short information about scope and objective, hazards (very generic), reference to a safety department standard regarding personal protective equipment, and reference to safety data sheets in a separate database. There are three hazard pictograms as well, without explanatory text, and some general advice, e.g.: "Contact the supervisors if you are unsure about anything" and "Read the whole instruction to understand what we are about to do."

The next 5 1/2 pages consist of an embedded checklist. Beside the action descriptions, there are empty columns for comments by the user, time, and signature, at each step. The first 7 items are about specific technical preconditions, e.g. "All safety valves in service", to be signed off by the operations engineer. Next, there are 3 items for the refinery shift manager on duty. One is rather broad, notably:

> Before starting charge pump, an inspection of the unit should be completed. The purpose is to ensure that operators can do their tasks in a safe way during the start-up...(etc)

The remaining 65 items are step-by-step actions to be conducted by operators, either in the control room or in the plant, e.g.:

> Increase the level in (vessel equipment no. withheld by researcher) to 80% on (level indicator equipment no., withheld by researcher) if we have some feed to the unit. Otherwise keep normal level.

This example seems to confirm that the instruction is indeed written for "users that are familiar with affected systems and equipment", as stated in the procedure writing guideline.

Between some of the 65 steps, there are yellow fields with de facto sub-chapter headings, additional comments, tips, and warnings, that don't have the columns for sign-off. There are 17 of those yellow fields in total. One reads: "When tubes are free of water, warm media flushing is started as follow:" followed by the steps in the checklist format. The idea with the yellow fields makes sense to the researcher, but it seems that some of the comments, tips and warnings would perhaps be better to include as checklist items, e.g.:

> Check steam injections on the A-furnace by:
>
> - Open the steam
> - Open/adjust drain valves so that the pipes are heated, and the steam is dried
> - Ensure that the reducer valves are ok

On the last page, there are some additional headlines. Under "document handling", the following is stated:

> Important that the master copy is updated. The master should be signed off in the control room and handed completed to the operations engineer.
>
> Note: Items that are not signed-off must be re-done before the furnace can be considered shut down.

The emphasis on rigorous signoffs makes sense to the researcher, but there could be practical difficulties (discussed below, under the theme heading: "Signing off and writing comments during use").

Emergency operating instructions for furnace fire

There are in fact two emergency operating instructions that are applicable in case of tube rupture and fire in the furnaces mentioned above. One covers specifically tube leaks in those furnaces. It's one page, with 9 steps to shut off all incoming flows to the furnace, which is the standard practice in scenarios involving loss of containment. There is no sign-off column. The revision date is as far back as 2007 (there is a company requirement, that instructions should be reviewed at least every 5 years, and given a new date and current names of issuer and approver).

There is also another emergency instruction, with 8 pages that cover 12 different types of emergencies in the unit where the two furnaces are placed. One is about fires, explosions or tube failures in the furnaces mentioned above. The 7 steps there seem to be partly different from the 9 steps mentioned in the first emergency instruction mentioned above. The revision date on the second instruction is from 2011. Questions regarding instructions that have not been updated as frequently as required are discussed further below.

A reflection based on the review of a few instructions

It appears that the organization is struggling to keep i the 5-year schedule for revisions of operating instructions, and in applying the procedure writing guideline and the template in a consistent way. This reflection was confirmed during the focus group discussions, as described in the following.

Transcripts and coding

Segments in the transcripts from the focus group meetings, in Swedish, were marked with codes as described in the method chapter. The codes were developed inductively ("ground-up") during the coding process, mainly based on the researcher's interpretation of the data (Braun & Clarke, 2006; Ritchie et al, 2014). The codes are shown in Table 3 below.

Table 3

The list of codes

Code#	Description
1	Often not used for simple/frequent tasks (even when instructions exist)
1a	It can be discretionary whether to use an instruction or not
1b	Poor knowledge about existence and location of instructions
2	Used/appreciated for infrequent/complex/new tasks
2a	but sign-off and comments can be poor sometimes
2b	sometimes instructions are reviewed before job, with supervisors & workers
2c	Operations engineers can prescribe use of an instruction
3	Updating is cumbersome and/or slow
4	Can be ambiguous (e.g. lacking detailed information)
4a	and/or impractical/cumbersome to use
5	Not always updated
6	Shift change challenges
7	Control room vs plant coordination
8	Adaptations occur (can even be necessary) (normally after review/approval by shift supervisor/shift manager/op. engineer)
9	Unauthorized/undesirable deviations/violations occur
10	Team work to reduce errors
11	Managers'/supervisors' support varies
12	Generally "low-blame" when errors/violations/incidents occur
13	Difficulties with document system
13a	Difficulties with work flow (write/review/approve/publish)
13b	Difficulties finding an instruction
14	Operator involvement in writing/updating (& resource allocation generally?)
15	Sometimes an instruction is partly applicable
16	Lack of information about new/updated instructions
16a	Little focus on instructions during training/re-training
17	Production pressure, goal conflicts
18	Views about Model 1 and Model 2?
19	Various factors affect need for procedures, e.g. infrequent or complex tasks, experience and training, tiredness, shift changes
20	Can instructions promote dangerous "working without thinking"
21	Adaptation when instructions don't exist or are not fully applicable
22	Unrealistic demands on operators
23	The need for detail depends on level of experience
24	Inconsisten format and level of detail
25	Potential advantages and disadvantages with new template
26	Emergency procedures are used and useful
27	Problems with new/modified plants and equipments
28	The work permit procedure is demanding
29	Applicable instructions don't always exist
30	General attitudes has improved over years
31	Recent/ongoing efforts to update and improve the instructions
32	Improved completion of instruction checklists (filling in during use)
33	Reliance/dependence on shift managers/supervisors to initiate use

Thematic analysis

Based on the researcher's assessment of the codes and the quotes, the following nine themes were developed (Braun & Clarke, 2006; Ritchie et al, 2014):

1. Writing and updating
2. Format and style
3. Information and training
4. When and why are they used (or not)
5. Signing off and writing comments during use
6. Authorized deviations ("adaptations")
7. Unauthorized deviations ("violations")
8. Fear of failure or blame
9. Finding an instruction (or not)

A table of codes, themes, and quotes, translated to English, is included in the appendix. For each theme, the researcher's findings are summarized below, with pertinent quotes (translated from the transcripts). Words in brackets within the quotes are clarifications by the researcher.

Writing and updating

A typical problem in Model 1 can be that procedures do not work in practice, because the people who write and issue them lack understanding of local context and practices (Hale and Borys, 2013a). At the case study plant, the operating engineers, who traditionally write and update most of the instructions, generally have a lot of relevant experience:

> It should be the operations engineer, and in this place, they usually start as an operator, then become supervisor, and then operations engineer. Or they go from experienced operator to operations engineer and build up local knowledge. It is uncommon that we bring in operations engineers from outside. Rather, they have built up knowledge internally in different roles. (Operator, Group 1)

Hence, the operations engineers usually have good knowledge about the practical operational aspects, which is needed to be able to write useful operating instructions. However, due to the large number of operating instructions, it can be difficult for them to allocate enough time to keep the instructions updated and to develop their usability.

Completely new instructions are issued mainly when new units are constructed, or new process equipment is installed. More frequently, there are modifications of existing units or replacements of equipment, where an existing instruction needs to be updated. Such modifications occur regularly, especially during years with major plant shutdowns for maintenance and upgrades. Modification procedures should ensure that instructions are updated in good order, but it seems that does not always happen:

> When we get new equipment, there is never any instruction, it's up to us to solve the task, and then the instruction can be written. (Operator, Group 3)

From time to time, operators make oral comments or write emails to the shift area engineers about anomalies in instructions and suggest changes, in line with Model 2. Lack of response can cause frustration. It should be pointed out that new and updated instruction should be reviewed by another qualified person and approved by the area operations manager before being released. That process can also contribute to delays.

> The problem is that it takes time to get a change done. First it must be written down, then reviewed and then approved and published. It's a messy system too, so people get fed up. (Operators, Group 1)

> I have sent emails to the operations engineer, but the instructions have not been changed. The reply is often: "do it yourself". (Operator, Group 2)

> We tell the area shift manager, and he sends an email (to the operations engineer). Then, if anything is done, I'm not sure…You don't bother to make a comment, it's too much

> work. You can send an email to the operations engineer and get a reply, "do it yourself". (Operators, Group 1)

One specific issue, raised by several informants, was the document system. It seems to suffer somewhat from poor usability. Lack of training and practise in the use of the system can also make updating cumbersome and time consuming, especially for infrequent users.

> Operators can assist in making an update, but we have not received any training about the system. (Operator, Group 2)

> When you haven't worked with it for some time, it get's hard, things are spinning around in those work flows...It's not very user friendly... An instruction can take two days to transfer to the new template, even if I don't change a single step. (Engineer, Group 4)

Especially in recent years, some of the shift operators have been asked to assist by making draft updates of instructions. This is clearly in line with Model 2, and the operators who had been involved seemed positive about the idea:

> Some of us have edited instructions with proposed updates. (Operator, Group 2)

> We have worked a lot with updating (and transferring instructions to the new template). A lot of things we were not sure about, then we have asked around: Is this really right? Or, if we did it this way, maybe that would work better? (Operators, Group 3)

However, there are limitations regarding operator involvement:

> An experienced operator could give input to the Area Shift Manager, but we don't have the time to sit down and write instructions, unless you are relieved of the normal work (Operator in Group 1)

> It would be great, if we sat down and read new instructions, and check in the field if they are workable. But we are not there today. (Operator, Group 1)

> The way I see it, changing an instruction should be done by the engineer. They have written most of it from the start. Why should we do it? (Operator, Group 2)

> The problem is that there are large variations in the amount of interest, in the template, word processing, writing and computer literacy. (Engineer, Group 4)

Overall, it seems that both operator involvement, and the emphasis on keeping instructions updated, has increased in recent years: "Updating is getting better and better, the priority has increased". (Operator, Group 2)

Format and style

The format and style of instructions seem to vary a lot, due to historical developments and the number of people involved in writing and updating them over the years:

> Many different people have written them, they are not the same...some can be very good, some are not so good. (Operator, Group 3)

The level of detail in each instruction has to be a compromise, since the operators who might use an instruction can be more or less knowledgeable about a particular task. For complex and infrequent tasks, even operators who have worked many years at the plant appreciate detailed instructions.

> Someone who has been here since 2013 might not have experienced a plant start-up, it can be 8 years in between. And even if he has process operations experience, he may not know how it's done on that unit...Someone who has been here 40 years, when starting a compressor, it can be 5 years since he worked on that unit, so he won't know about it. (Operator, Group 2)

The internal guideline for how to write instructions states that "it is a requisite that someone who use the instruction should be well acquainted with the plant or equipment involved". In reality that seems to vary:

> We often say that an instruction should be clear enough so that a beginner can follow it...But some conservative people say, if it's just to follow step by step, the operator will not understand and think, just do the steps. (Operator, Group 2)

> Instructions can be written for the very experienced. With a few words the operator should know how to do. Instead of writing more specifically what to do and why. (Operator, Group 2)

> They write for those who have done it before. Some are written so that anybody can do it from the start. (Operator, Group 3)

> It was said (during the migration to the new document system) that instructions should be written for people who did not know anything (Operations engineer, Group 4)

An external consultant, specialist on the design of technical documentation, was involved during the migration of operating instructions to a new document system few years ago. A new template was also introduced. The idea was to standardize the format and style in accordance with modern principles for the design of instructions. It seems that both the template and the consultant's coaching suggested a level of clarity and detail that was considered too high in some cases, at least by the experienced people.

> She (the consultant) wrote an instruction, but she didn't understand, so he (an engineer) did it in a way that she could understand...But we don't work like that here, you have some education before you get inside the gates, and you get trained before getting it (an instruction) in your hand (Operations engineer, Group 4)

There were different views among the informants about the amount of extra information prompted by the template, compared with the traditional format, e.g., hazard pictograms and warnings, environmental aspects, table of contents etc. At least the experienced people seem to prefer to have mainly the actual tasks in the instructions (what to do, step by step), and safety information only about the most significant task specific hazards.

> It (the new template) is perceived as rather cumbersome, there are very many pages to print, for no good reason if you ask me...There is too much extra information, so you can't see what's important in the instruction...(Before,) pre-conditions came first. Now there is a table of contents, if it's a long instruction, then there is Aim, Scope, Safety and Risks, Environmental Aspects and Legal Aspects, things like that, and the hazard pictograms...There will be many pages to flick through before you get the real thing. (Operations engineer, Group 4)

However, the way that the new template has been implemented varies. It seems that in many cases the older versions have been pasted in with minimal adjustments, probably due to pressure of other work.

> Yes, but it's also how you use it (the new template) ...Some have used it quite well. Maybe we should have been more clear in the internal guidelines, how to use the first part of the template and what to expect of different instructions, so that they don't get too long. (Operations engineer, Group 4)

> In the beginning (of the updating/migration project), they became very detailed, but now it's more or less the old instructions copied into the new template. (Operations engineer, Group 4)

On the other hand, it seems as if both the introduction of the template and the involvement of operators has had some positive effects:

> It (the new instruction template) is good, it's easier to get an overview, clearer...It's probably good to harmonize a bit...Another good thing with the new template is the safety information in the beginning. Whether you check it, but it's good that it's there. (Operator, Group 3)

> We (operators updating and migrating old instructions to the new template) add a lot of comments too, why we do things. Also, pictures, for example where to put a pressure gauge. If there is a picture, you know exactly where to put it. (Operator, Group 3)

> The main difference is that every action should be a separate item. It should not say: "close the drain and open the inlet valve". It should be two items, one for each action. Then there are other things I think is so-so, like the hazard pictograms and things like that. Things that are not implemented, that we don't use etc. (Operations engineer, Group 4)

Information and training

When operators are new to the plant, or new on a particular unit or position, training is mainly on-the-job with an experienced colleague. There seems to be no formal requirement or check-out regarding familiarization with instructions. Instructions might be studied and used for advanced tasks, depending on the individuals' inclination, but seldom for routine tasks. As a result, the exact way of doing some operator tasks can vary:

> You work with an older experienced operator who shows you the job. There are instructions, but they might not be updated. (Operator, Group 1)

> We are often trained by someone with experience, and he thinks in one way, then you work with someone who thinks in a different way. (Operator, Group 2)

More formalised and recurring training sessions are conducted mainly for emergency instructions:

We often review them (emergency instructions) during annual emergency training. (Operator, Group 2)

When there are changes in instructions, affected operators should be informed via the shift area manager. This seems to work mainly for particularly important and imminent changes, e.g., operating limits, or procedures for an an upcoming plant shutdown or start-up:

> For some instructions, we write in the operational requests, that an instruction is updated, e.g., if the max temperature in a reactor has been increased, then we usually write it there. Otherwise, we mention it in the weekly area staff meeting minutes. (Operations engineer, Group 4)

> We are instructed by the operations manager to go through the meeting minutes, and all the updated instructions should be mentioned there. We should inform the shift about those. (Shift area manager, Group 4)

> We may have slipped, things have been hectic recently, so maybe it's not mentioned. (Operations engineer, Group 4)

> It's (real) changes that should be mentioned. That has worked quite well, I think. (Operations engineer, Group 4)

Some changes only become relevant some time after an updated instruction has been released:

> If it's a start-up instruction to be used during the turn-around in 2022, we don't have to say that, they will see when they print it at that time. (Operations engineer, Group 4)

There is an understanding that operators should check the current version in the document system before using an instruction and print a copy if required. Actual changes since previous revisions are not highlighted in the text normally, but the release date and/or the change log could give some clues about changes:

> One looks at the approval date, then you see if something has happened or not. That's something good about the new template, that the latest revisions are listed. That's a good thing, as it's mentioned at the top. (Operations engineer, Group 4)

> We don't get information; we just see it in the system. That's how I experience it... At one stage, we got an email about each update, with a link to the instruction, with the changes underlined. That was great. But it didn't last for long. Now you have to read all of it and think, what have they done now. (Operator, Group 3)

> Instructions from other departments (e.g., HSEQ) never gets communicated to us. They are difficult to find in the system too. (Shift manager, Group 4)

To summarize, ensuring that every affected operator is informed about every new or changed instruction is a challenge, due to (e.g.) the large number of instructions and rotation of operators. Lack of time among the operations engineers, and the operator's shift work, probably limits the dialogue between those involved in the writing and updating, and the affected operators on all shifts.

When and why are instructions used (or not)

The operators use, and generally seem to appreciate, instructions and checklists for advanced non-routine operations. For example, the rigorous work permit instruction, which is managed by the Safety Department, requires the daily use of operating instructions and checklists for isolating and safeguarding equipment before maintenance work.

> We use instructions and fill in check lists every day. (Operator, Group 2)

Other well received and used instructions are those that involve many operators and/or more than one shift, such as mode changes and shutdowns or start-ups:

> It's mainly for infrequent jobs that we use the instructions. If I, for example, disconnect a gas tanker, I really check the instruction. (Operator, Group 1)

> Some tasks, that you do seldom, that's when you bring out the instruction. (Operator, Group 2)

> When you change crudes, you really want a good instruction. (Operator, Group 2)

> Some tasks must be done in a certain order, a plant shutdown or start-up for example. Then it's a must to have an instruction, to follow the stages. (Operator, Group 2)

The emergency instructions also seem to be well known and appreciated, and actively used when applicable:

> In emergencies) the shift manager or area shift manager usually comes to the control room with the (applicable) emergency instruction. (Group 2)

Some tasks, where an operator is involved perhaps a few times per year or less, e.g., switching two compressors between running and stand-by, can be quite complicated and critical from both safety and production views. Using the applicable instruction could indeed be helpful, but it is not enforced consistently in the same way as in the other examples mentioned above.

> Often, engineers' operational requests make reference to an instruction. (Operator, Group 2)

> In other cases, start of a compressor or something, I don't have to hand out a printed copy with a master in the control room, the shift does that. But I have told my people, if the procedure goes across the shift change, they have to fill it in. (Operations engineer, Group 4)

For routine tasks, the available instructions don't seem to be used a lot. For example, there are quite standardized tasks across generic equipment items, such as switching two pumps between running and stand-by. It seems generally accepted that such tasks are done based on tacit knowledge.

> We don't need them for everyday jobs (Operator, Group 1)

> It's not every shift that we bring out an instruction. It depends on how the plants are running. If it's only standard stuff, it can be a whole week without the need for an instruction. (Operator, Group 3)

> It depends on how long you have been employed, in this group many are quite new, off course they need (instructions). Others, who have worked here for 30 years, can manage in a different way. (Operator, Group 3)

Using paper copies in the field in varying weather conditions and without a shelter or desk at hand, can can be quite impractical (the actual plant is nearly all "open-air"). Portable electronic devices for access to operating instructions in the field have not been introduced.

> It's not always that we take a print-out into the field. (Operator, Group 2)

Signing off and writing comments during use

A unit start-up can take several days, and it's a complex and potentially hazardous operation. The use of start-up instructions is quite formalised. The instructions generally have embedded checklists, with columns for signature, date and time, and comments. The importance of using them was acknowledged by the informants:

> We are quite strict about sign-offs (during plant start-ups)...if it's not signed you have to go back and check and then sign (Operations engineer, Group 4)

> I say it's useful (signatures and comments in instruction's checklists). If you're not ready at the end of the shift, the new shift will know where they are. Otherwise, one has to go back and check what has really been done, as handovers are less than good at times. (Operations engineer, Group 4)

When a unit is getting ready for start-up, the operations engineer and the shift manager on duty fill in the first parts of the checklist (preconditions etc). This "master copy" is handed to the control room operator.

> Before a plant start-up, I bring the instruction to the control room, it says "master" and it has to be filled-in and returned to the operations engineer when completed. (Operations engineer, Group 4)

The control room operators follow the steps and take actions, either via the control panels or via radio calls to outside operators. Each completed step should be signed off by the control room operator on the master copy.

> Mostly during start-ups and shutdowns, the control room operator has a "master", where we sign off steps that are completed or under way. (Operator, Group 2)

It is quite common in reality that steps are overlapping or initiated and/or completed in a different order, for practical reasons and/or to save time. Such adaptations, and any anomalies or deviations from the instruction, should be noted in the "comments" column.

> The worst can be when you start a new shift, you might get a hand-over that "we are at step 27", but 24, 23, 22 might not be ready. (Operator, Group 2)

Lack of, or ambiguous signoffs and comments can be a problem:

> It (a note in the comments column of a filled-in check list) can say "completed to step 7". Do they mean that step 7 is completed? Then you must go and check anyway...we hand over to the next shift and then they hand over to the next...that's when the errors occur. (Operator, Group 1*)*

> It's happened to me a few times that steps have not been signed off, and no hand-over information either. Then I have to check with the outside operator what's been done…Those are the worst jobs, just running around to double-check. (Operator, Group 2)

Setting a good example, as when the operations engineer and the shift manager fill in the first steps about preconditions before the master is handed to the control room operator, seems important:

> When the person who starts signing off the instruction does it correctly, it has a tendency to continue. Especially when (an engineer) hands over a start-up instruction, and it's signed off (by him/her), that we have checked alarms and all those things (preconditions), and takes it to the shift manager who fills in his items. Then, when it's taken to the control room, as a master, it's difficult, if it's properly done from the start, to start being careless. (Operations engineer, Group 4)

During complex operations such as unit start-ups, the outside operators rely on the control room operators to give instructions via radio to a large extent. It can be hectic for the control room operators, and difficult for the outside operators to maintain a good situation awareness since they don't have access to the filled-in master copy.

> A problem that I have seen is that the outside operators don't have access to that. It's up to the control room operator to guide the outside operators...It would be better if everyone had access to the same copy (the "master"). (Operator, Group 2)

When the operation is completed, the filled-in checklist is returned to the engineer, who will check that it's filled in properly. If operators have made notes about anomalies or deviations, changes in the instruction should be considered.

Authorized adaptations and deviations

Operators as well as managers and engineers seem to agree that instructions can't cover all circumstances, and that adaptations as well as outright deviations are motivated at times.

Especially in the last 5-10 years, operations managers have emphasized the importance of getting approval before deviating, and to discuss adaptations and deviations openly. Operators are not allowed to deviate from instructions without prior approval. Hence, they regularly discuss such situations with their nearest supervisor, the area shift manager:

> One gets into situations that doesn't really fit the instruction, then we have to discuss, how to make it safe anyway... If we are not sure, we have the area shift manager and each other to discuss with. (Operator, Group 2)

> If there is an instruction that is not possible to follow, at least on our shift, we discuss everything before deviating, and we might ask the area shift manager, "can we do like this". (Operator, Group 3)

The refinery shift managers and the operations engineers have clear mandates to decide on deviations:

> Shift managers do (have the mandate). It's partly to avoid calling the operations engineer in the middle of the night, or on the weekend. It's a mandate to do the best thing. (Operations manager, Group 4)

> They are large and complex plants; things happen that can't be foreseen. You can't write an instruction that covers all possible cases. If you're stuck in the middle, a decision must

> be taken, and it's usually done by the shift manager. It's not often that the engineer is called, it's usually solved on-site by the shift. (Group 4)

On the other hand, if it's a complex issue, operations engineers are consulted, and sometimes a job is delayed to allow for further discussions during day shift (including a risk analysis in some cases).

> (If) there are isolations that are not keeping tight, in the end you have to try alternatives. They can be more or less discussed, but often it has been discussed, sometimes for several days, so many people might be involved. (Group 3)

It would be difficult for the refinery shift managers to be fully informed about all operational issues on the whole refinery. Hence, decisions are often taken jointly with the area shift manager involved:

> If we are deviating, it's not just me who says, "do this". I discuss it with the area shift managers, even if it's not like a documented risk analysis. (Refinery shift manager, Group 4)

> When we talk about start-ups and things like that, when the shift manager and area shift manager decide together about deviations, it's not so much that a step in the instruction is impossible to follow, it's that we are in a situation that is not really covered in the instructions. (Area shift manager, Group 4)

It is unclear whether there might also be a "grey area" in actual practice, where the area shift managers sometimes decide about deviations that they consider straight-forward, without involving the refinery shift manager:

> We sometimes deviate from instructions, but there is a dialogue before we do it (Area shift manager, Group 4)

> I don't know how clear it is, in writing, but the ambition is that the area shift manager is not allowed to do it (deviate) alone, you must involve the shift manager. (Operations manager, Group 4)

Unauthorized deviations ("violations")

According to Group 4, attitudes towards instructions has changed significantly in the last 5-10 years, at least in the process units (Area 2 and 3):

> Most aspects regarding instructions...has changed in the last 5-10 years...A few years ago, we (area operations managers) decided that "the new black" was to follow instructions. At first it was like a joke, but then we started to really explain why. Then we got back demands for instructions to be usable. We have not achieved 100%, but we are getting better at keeping instructions updated which also creates trust. (Operations manager, Group 4)

However, it seems quite clear that there is a problematic heritage, where rules and instructions have been compromised for practical reasons and in the interest of production:

> There used to be a culture, no question about it, when shifting pumps, the first thing you did was bypassing the safety function, so that the furnace would not trip...When I worked at the cracker (years ago), everything was about keeping the damn thing going for as long as possible. We did anything to avoid a shutdown. (Operations engineer, Group 4)

> Before there used to be many instructions that people didn't care about, they were not considered necessary. People knew anyway. And sometimes they were not followed because they were not updated, or difficult or impossible to follow...The experienced people (used to say) "following the instruction has never worked. I do it this way instead." (Operations engineer, Group 4)

It seems that it's still not totally uncommon that operators deviate from instructions without approval, sometimes secretly and sometimes with quiet acceptance from engineers and managers. In Group 1 there was a particularly scathing comment:

> I think that we deviate from that instruction very often…the feeling we at the bottom have, is that there are so many documents, produced at the desk level. Can we at this level do the job in that way? Doubtful…We don't follow all the rules when we drain a tank, it's up to me if I go to the fire station to get a mask before draining, to protect against the fumes...I think they (management) know about it (deviations in general), they would have to. (Operator, Group 1)

The operators in Groups 2 and 3 also gave examples of deviations that could still be quite common in the process units. There seems to be pressure on time and production at times, actual or perceived.

> When there is an outage, there is lots of talk about starting up, then it feels like things are not so strict...The limits are stretched more, the longer it takes...During plant start-ups, there are some tricks that can be used to make it go faster and easier. If you follow the instruction, (those tricks) are not allowed, but others do it and get the plant going, and then they are praised...We say that things (preparing work permits) should be allowed sufficient time, but then engineers come and say, "we have to get things going now". (Operator, Group 3)

> If you try to follow instructions very thoroughly, you can be seen as difficult, for taking too long. Someone on a different shift doesn't bother with some steps, things will go faster for them. That's quite often. For example, when taking a pump into service, the temperature should be increased with 50 degrees per hour, nobody follows that, it would take...maybe 8 hours and nobody would accept that. (Operator, Group 3)

> To drain the Merox tower, we should first drain to a vessel, then pressurize that and let down to storage tank. Instead, you can drain straight to tank. There are little things like that. It's not better, but with some instructions, things can be done quicker. You can't teach new operators such things, you learn it by yourself. (Operator, Group 2)

In the latter example, some of the informants argued that there would be an increased risk of hydrocarbon release due to the "alternative practice". Some deviations might be due to lack of information about the reasons for certain procedures, or ineffective enforcement:

> During night shifts, we should check that stand-by pumps are kept warm, otherwise you might get a leak if they cut-in. The routine says it should be checked every night, but it's quite often that I find cold pumps. Could be that operators are tired during nights, or laziness. (Operator, Group 2)

Some instructions might just not work in practice, due to equipment design or reliability problems:

> If we follow the instruction and flush with cold gas oil before draining, the drain will plug. If we open the drain a bit when it's still hot gas oil, things will work in practice, but you can't write that in the instruction (hot liquid is not allowed in the sewer). (Operator, Group 2)

> When there is a recurring problem, you get used to handling that problem, and that can mean deviating from an instruction. It can be fire alarms for example, or gas detectors, alarming every now and then. We can't take it seriously every time…we can't call the fire brigade every time. (Operator, Group 3)

Fear of failure or blame

Performance variations ("errors") that has led to process upsets or equipment damages happens from time to time. That typically leads to questions and perhaps some embarrassment for the people involved. However, it seems that people would not normally be punished or held formally accountable for violations or errors. One informant stated that feelings of guilt would be the worst if anyone should contribute to someone else getting injured by accident. Fortunately, such accidents have not happened at the case study plant for many years.

> Generally, we don't get hanged if we make errors, because everyone does them, more or less, and usually it's not so serious. Sometimes it costs a lot, but so what, if nobody is killed or injured. (Operator, Group 1)

> As long as you know what you're doing, it's ok. (Operator, Group 2)

> If something goes wrong, somebody will ask, why did you not do this, or why did you not nitrogen purge for as long as it said (in the instruction). (Operator, Group 3)

> We have not set an example ever, as far as I can remember, against people who don't follow instructions. (Operations manager, Group 4)

Finding an instruction (or not)

Most informants, operators as well as managers and engineers, find it difficult to find particular instructions, and to get an overview of all the instructions that may be relevant for them:

> It's very difficult to find things in the management system...It was much easier before (in the old system) ...Rather than taking the time to find it, I don't bother. (Operator, Group 1)

> Sometimes it can be difficult to find a certain instruction. You must write exactly right when you search, either the instruction number or the pump (equipment) number, and then it can matter whether you use a hyphen or not. If there is an instruction that you don't know if it exists or not, it would be good if the search is not so specific. (Operator, Group 2)

> When we transferred all the instructions to the management (document) system, for better and worse, it became difficult to find things. It's a bit better now but it's still a problem. We may even know the name (of the instruction), but we must spend an hour to find it. (Operations engineer, Group 4)

> There is a training need there. The instructions are not in a certain place, they are just tagged. If you make a spelling mistake and don't find an instruction for the equipment I'm searching for, you don't know where to start looking...even for me who is interested and understand a lot about these things. For those who don't, it's even more of a hindrance. (Operations engineer, Group 4)

It seems that the system is not very user friendly, and that little training has been provided about the structure and the use of the system. Many operators might be disinterested, or frustrated about the system, and that probably limits the use of instructions to some degree.

> Those who seldom look at instructions, they may also find it difficult to find them. It's not just that they think that they know it (the task), they also think it's easier to do things without having to use the computer. (Operations engineer, Group 4)

However, one of the operators (at least), probably with above average computing skills and interest in the instructions, had apparently learned to use the system quite well:

I think the filter options (in the system) makes it easy, there is some clicking, but it's always possible to find, I think. (Operator, Group 2)

Discussion

Balancing Model 1 and Model 2

Based on the literature review, the focus group discussions, and the researcher's experience, operators sometimes deviate from rules and instructions, knowingly or unknowingly, nearly always in good faith, but sometimes without fully understanding the risks. Casual deviations can result in serious accidents. Hence, it makes sense for organizations to "invest in people's knowledge of procedures and ensure that procedures are followed", as stated in the original definition of Model 1 (Dekker, 2003, p. 233). However, the Model 1 definition is attributed to authoritarian organizations, where "experts", who often lack understanding of local context, write the rules and and procedures, and workers should follow them strictly, almost without thinking (Dekker, 2003; Hale & Borys, 2013a). Today, that seems like a caricature, at least in countries and organizations with a more democratic culture.

On the other hand, instructions can't cover all eventualities in complex operations. Interpretations and adaptations will often be motivated, or absolutely necessary, but they should be mindful. Hence, it makes a lot of sense for organizations to work towards Model 2, and "develop ways that support people's skill at judging when and how to adapt" (Dekker, 2003, p. 235). In reality, based on the focus group discussions, and the researcher's experience, most process plant operators in Sweden might deviate from instructions that don't make sense to them, either quietly or in collaboration with colleagues or supervisors. At the case study plant, it appears that there has been a shift in recent years, so that operators now frequently discuss operating instructions, and possible adaptations, with shift area managers and engineers. Operators also get involved in the writing an updating of instructions, at least to some degree. The researcher posits that this type of "Model 2 practices" has developed without much knowledge about "Model 1 and Model 2 theory" among practitioners. It probably has more to do with general trends in management practices.

To summarize, both the literature review and the focus group discussions support Model 2, but organizations should still invest in quite detailed operating instructions and check lists, especially for safety critical tasks, and encourage operators to use them.

Usability

The format and style of operating instructions (and procedures in general) should be appropriate and adapted to the complexity of the task, the potential severity of accidents and the competency of the people doing the task. Especially the latter makes it difficult, since the level of competency and experience will vary when there is a mixture of people that do the task from time to time. Some might be beginners; others could be experts.

Operators' perceptions about procedure's quality and usefulness are crucial for their attitudes towards using them, according to Hendricks and Peres (2021). In their survey among procedure users in high-risk industries, the most common complaints were:

- Conflicting information
- Inaccurate information
- It's easier to do the task without a procedure
- Time-consuming
- Not enough information
- Too much information
- Difficult to understand

Those results are in line with the findings from the focus group discussions. For example, experienced people in the focus groups might find the instructions too detailed, although the guideline for writing operating instructions states that the level of detail should be directed towards operators familiar with the task and the equipment. Very detailed instructions can be useful for beginners, but tedious and frustrating to read and use for experienced operators. Detailed instructions can also invite deviations, if they are poorly updated or don't describe an accepted 'best way'. To improve the perceived quality and usability of operating instructions, operator involvement is essential, while operations engineers should still be 'owners' of the instructions. Appointment of a talented writer as "writing coach", and development of an internal 'writer's guide' could be worthwhile, to develop and maintain appropriate format and style (discussed below under subchapter "Writer's guide and support").

Different types of activities

Linear safety-critical activities

Preparing process equipment (e.g., a compressor) for maintenance is an example of what the researcher calls a linear safety-critical activity. It typically involves stopping and de-energizing the motor, then shutting valves to isolate the equipment from "live" systems and opening other valves to depressurize. The valves are tagged and locked in the correct position. A work permit is issued to enable fitters to install blind flanges (or spectacle blinds) on the compressor side of the closed valves, to protect against passing valves. An operator checks that this "positive isolation" is complete before issuing a work permit for the actual maintenance work on the equipment.

For some types of maintenance activities, a second person must double-check each step and countersign the checklist and/or the work permit. Passing valves can sometimes make the work complicated, which can lead to stress if maintenance crews are held up, waiting for the work permit. Failure to follow the procedure can result in gas release, fire, explosion, and serious injuries to people and damage to the environment and/or property.

In the case study plant, there are step-by-step instructions, and check lists for signing-off each step, for numerous equipment items. The focus groups expressed strong support for the importance of those instructions and checklists, and a high degree of compliance. In the researcher's experience, similar procedures are generally viewed as an essential "best practice" in the process industry. Ensuring that people know about and follow these types of instructions, as alluded to in Model 1, seems indeed essential for this type of activity. However, adaptations in the spirit of Model 2 can also be necessary, when there are faults or ambiguities in the instructions, or problems in the plant.

Complex activities

Start-up and shutdown of process units, or other major mode changes, are very complex activities. There are numerous steps, concurrent activities and dynamic and interacting process conditions and events. Many employees are involved, both in the control room and the field, and shift changes often take place before the procedure is completed. In the case study plant, the focus groups explained how the control room operators, in particular, need to jump back and forth in the instructions depending on e.g., the actual duration of each step, as that can be different from what was foreseen when the instruction was written. Also, more efficient, and practical ways to proceed may have been invented, that are not reflected in the instruction. The control room operators also give directions to the outside operators via radio and discuss adaptations with area shift managers and engineers. The focus groups stressed that the instructions for this type of activities are extremely useful and very important, but insufficient, for safe operation. Teamwork, experience, tacit knowledge, and cognitive capacity are absolutely necessary. Hence, organisational strategies in line with Model 2 seem appropriate indeed for this type of instructions and activities.

Routine activities

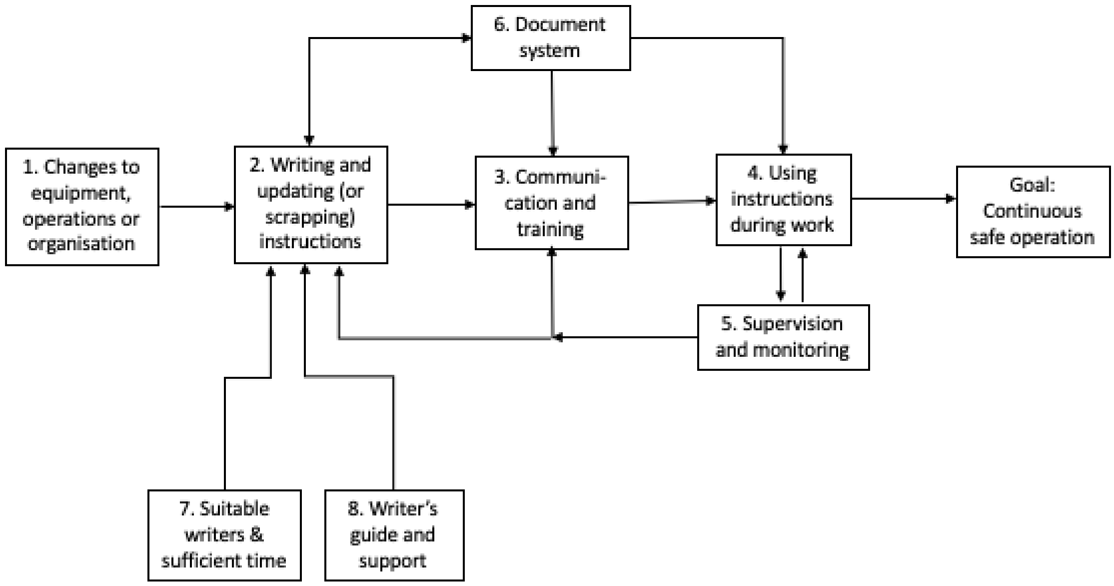
A lot of operator work is highly routinized, especially for the field operators. Typical daily tasks are, for example: Taking product samples, draining water from storage tanks, and switching between running and stand-by pumps, compressors, or filters. Operating instructions exist for many such tasks, but the focus groups made it clear that those instructions are rarely used. New operators, or operators who change jobs, learn mainly by working together with an experienced colleague. Some might read the instructions, usually on their own initiative, but that's not very common. The focus groups did not seem to regard this as a safety problem, since all new (and old) employees have a basic aptitude for the job and become sufficiently familiar with basic procedures and safety aspects during their introduction and on-the-job training. Hence, it seems that neither Model 1 nor Model 2 is applicable for this type of activities. The researcher still suggests that those instructions should be reviewed in order to identify all significant safety aspects and ensure that those are somehow highlighted and emphasized during training and re-qualifications. Quite a lot of work is required to produce and maintain this type of instructions. It could be discussed whether some of them could be simplified, merged, or even scrapped, to free up time for development of the instructions for safety-critical and complex activities.

A framework for the development and use of operating instructions

Based on the results of the analysis a framework for the development and use of operating instructions is proposed. It is inspired by a similar diagram used by Hale and Borys (2013b, p. 224), described as "essentially neutral between Model 1 and 2", with "a cyclical nature, emphasising...that rule management is a dynamic process of adaptation... (Model 2)".

Figure 4

The researcher's proposed framework for the development and use of operating instructions



The topics in each of the numbered boxes are discussed under the following headings.

Changes to equipment, operations, or organisation

In process plants, there are usually numerous changes to equipment or operations, as companies strive for efficiency and success. Usually, such changes will create a need for new or updated operating instructions, that must be dealt with by the organisation. For example, in the case study plant, a new process unit was constructed a few years ago, which resulted in numerous new operating instructions. Organisational changes mean that the owners of instructions, and the operators affected by them, change from time to time, with implications for e.g., updating and communication and training.

Writing and updating (or scrapping) instructions

Existing instructions need to be updated regularly, in case of changes and based on monitoring. In addition, a maximum time interval between review of each instruction seems useful, e.g., 5 years, as at the case study plant.

Operators' perceptions about quality and usefulness of the instructions are key factors that affect their attitudes towards using them (Hendricks and Peres, 2021). Hence, operators should be involved in writing and updating instructions, which was actually occurring to some extent at the case study plant.

Some authors (e.g., Dekker, 2018) have suggested that reducing the number of instructions should be considered in some organisations or domains, to give individuals and teams at the sharp end more freedom to develop good practices for routine tasks, and good solutions to uncommon or unique situations. It could also free up time for developing the quality and usability of really essential instructions and make it easier for operators to find those and be familiar with them. In the case study, the informants did not appear too concerned with such aspects. Even though some instructions for frequent routine jobs are not actually used much, they are considered "nice to have" if inexperienced operators should need them.

Communication and training

As discussed above, instructions are essential for complex and infrequent operations, especially when there are many steps that need to be completed in a certain order and coordinated between several people. Hence, communication and training should indeed ensure that operators are familiar with the instructions, and encourage active use of them. Since most instructions are under-specified to some degree, operator's also need training about when and how to adapt, and how to assess the risks involved (Dekker, 2003). During the focus group meetings, it was mentioned that instructions for plant shutdown and start-up are reviewed in group sessions with operators beforehand. Also, emergency instructions are practiced or discussed with operators annually, and training and information about the work permit procedure is conducted regularly.

For straightforward routine tasks with relatively low risks, it's mainly on-the-job training at the case study plant, at first with an experienced colleague. Using applicable instructions during training doesn't seem to be common. Hence, if experienced operators are deviating from an instruction, the same deviation will often be repeated by new operators. It would probably be worthwhile to encourage the use of operating instructions during training, and to include some questions about that in the competence check-out procedures.

Important changes in instructions are communicated quite effectively at the case study plant, especially safety related changes that need to be implemented more or less immediately. Other changes can sometimes be released in the document system but remain unnoticed by the operators. The document system is discussed further below.

Using instructions during work

Plant start-up is a typical "Model 2 situation". In the case study plant, each unit can be "cold started" once every few years, and an individual operator may only be involved in the start-up of each unit a few times during an entire career. The control room operators in particular rely on the start-up instruction, in order to take the right action, or give the right instructions to the outside operators, at the right time. They must keep track of many concurrent activities and monitor a lot of process parameters on the panel displays. The steps in the start-up instructions, presented in a sequence, often need to be modified, rearranged, or run concurrently, due to practical issues in the plant. All this requires "substantive and skilful cognitive activity" (Dekker, 2003, p. 235).

The start-up instructions are in a checklist format, where the control room operator has to sign-off each step on a "master copy” and add comments about anomalies and adaptations. This is essential so that an incoming shift can know the state of the plant and the start-up. The area shift manager and the operations engineers will also look at it now and then, in order to give advice and directives to the operators. The outside operators have printed copies of the instruction, but do not have access to the master copy in the control room. Therefore, they may not have a complete picture of the state of the plant and the start-up but rely on instructions from the control room operator about what to do.

Operators at the case study plant should consult the area shift manager whenever they find a need to deviate from instructions. The principle makes sense, since one person alone can easily overlook an undesired effect of a deviation, and the area shift managers are normally very experienced and competent former operators, who generally seem to have a consultative leadership style. As an alternative, in the spirit of Model 2, it could be possible to allow pairs of sufficiently competent operators to proceed with some deviations without prior approval from the shift manager. In practice, that probably happens every now and then, but it might be cumbersome to formalise.

Supervision and monitoring

Supervision and monitoring can be counter-productive in terms of safety, if practiced in authoritarian top-down style (Model 1), especially in complex and high-risk activities (Dekker, 2020). At the case study plant, area shift managers, operating engineers and operating managers seem to be quite open and consultative in discussions with operators, and between each other, about operational issues. Thereby, gaps between Work-As-Done (WAD) and Work-As-Imagined (WAI) (Hollnagel, 2014) can be identified and discussed, and the best way to do the task can be agreed and implemented in an updated instruction. This is in line with Model 2.

Systematic procedures for monitoring of compliance with operating instructions can also be formalised, e.g., behaviour observation or audit programmes. According to Hopkins, it has been shown that behaviour observation techniques can lead to improved compliance and reduced accident rates when it comes to rather simple and straightforward rules (Hopkins, 2011), but again, an authoritarian "top-down" style (Model 1) will drive deviations underground and be counter-productive. At the case study plant, formalised monitoring of compliance with operating instructions seems to be limited. A program for "observation walks" was implemented 15-20 years ago and has been developed towards a form of 1-to-1 "safety chats", either worker-worker or worker-supervisor. The effectiveness in terms of monitoring and enforcing compliance with instructions might be limited, but that question was not pursued by the researcher. Regular internal audits are conducted for some key procedures, such as work permits and isolations for maintenance, and by-passing of safety instrumented functions. Insurance companies also conduct some audits of key safety related procedures.

The incident investigations at the case study plant reviewed by the researcher included some recommendations to revise operating instructions. That is a common outcome of incident investigations in other sectors and organisations as well. The effectiveness could be questionable, or even counter-productive, if revisions are done as a "quick fix", but revisions make sense when deficiencies in an existing instruction are revealed by an investigation.

Document system

As mentioned, the informants were very critical about the document system. Nearly all had difficulties finding instructions at times. Similar problems have been reported in a study of workers knowledge of rules and procedures within the petroleum industry (Dahl, 2013), which pointed also to the signal value from management to workers when document system usability does not seem to be a priority. Those who are involved in writing and updating instructions also had difficulties with system functions like document tagging, due date reminders and the workflow for review and approval. It appears that the system is not very user-friendly, and only limited training has been provided since the system was implemented 4-5 years ago. Some super-users were appointed at that time, but at present they don't seem to be very active in training or coaching to other users. It seems very likely that these types of problems will affect people's attitudes towards the development and use of instructions in a negative way.

Suitable writers and sufficient time

In the case study plant, the operations engineers have traditionally been responsible for writing and updating operating instructions. That makes sense since they have usually been appointed based on prior experience and competence as operators and shift supervisors. Perhaps because they have that background, they don't feel a need to consult operators about the best ways to operate, which would otherwise be highly useful according to Model 2. Their ability to write well can vary between individuals, and they are usually very busy, torn between being out in the plant, meetings and acute problem solving. Hence, they seem to be struggling to develop and maintain high quality operating instructions. Some operators in the focus groups have recently been asked to assist with reviewing and updating some of the instructions in their area. When they finish a draft, it is sent to the area shift manager and the operations engineers for review and adjustments, then to the operations manager for approval and release. Sometimes this process is delayed due to other, more urgent work, which can cause some frustration.

Writer's guide and support

As mentioned, the guideline for writing operating instructions at the case study plant is rather brief, and the researcher suggests that it might be developed. According to WANO, a procedure writer's guide will "save time, money, and organizational frustration by defining detailed document standards" (WANO, 2020, p. 229). This is supported by Ahmed et al (2020, p.1): "A key element of the procedure development process is writer's guide, which dictates how these procedures should be written, reviewed and managed". The researcher has been inspired by an unpublished generic writer's guide produced at Texas A&M University (personal communication, October 27, 2021). An older, publicly available, guide about "Good practices with respect to the development and use of nuclear power plant procedures" (IAEA, 1998), was also found to be interesting.

An idea discussed with one of the informants would be to appoint and train a "writer's coach", someone with an operations background and some interest in, and talent for writing good instructions. Part of the job description would be to develop the existing guideline, rewrite some instructions as good examples, identify instructions that need extra work, and assist writers with advice and comments on drafts. It would be useful also to spend some time reading relevant literature about procedures, and perhaps take part in some basic formal training about human factors.

Conclusions

The theories about Model 1 and Model 2 are indeed useful, to understand strengths and weaknesses of different approaches towards the management and use of operating instructions for process plants. Both the literature review and the focus group discussions provide clear support for the advantages of Model 2, especially these elements:

- Monitoring and follow-up of gaps between work-as-done and work-as-imagined
- Involvement of operators in the development of instructions
- Acceptance of the need, and support, for interpretation and adaptation

However, organizations should continue to invest in the development of operating instructions, especially for safety critical tasks, and encourage operators to use them, which could perhaps be attributed to Model 1. A potential weakness in Model 2 would be if the rhetoric is misconstrued or exaggerated, so that the importance of operating instructions is played down, or too much responsibility and mandate is given to the operators in the development and maintenance of operating instructions and other safety related procedures. The operator involvement should not be at the expense of qualified engineers and specialists, who may have a better understanding of some technical limitations and process safety aspects.

Hence, to improve the actual and perceived quality and usability of operating instructions, operator involvement is essential, while operations engineers should still be the 'owners' of the instructions. The framework proposed by the researcher could support such a process. Appointing and developing a talented writer of instructions to become a 'writing coach', and development of an internal 'writer's guide', would be worthwhile to develop and maintain an appropriate format and style of instructions. Future research to test the effectiveness of such interventions ('action research') could be interesting and potentially useful.

Generalisability or transferability can not be claimed based on a case study of one plant. However, based also on the literature review, and the researcher's general experience from the process industry, the researcher propose that these conclusions would be quite valid for process plants generally.

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Appendix 1, Codes, themes, and quotes

Code: 1 (Often not used for simple/frequent tasks (even when instructions exist) Theme: 4 (When and why are they used (or not))	
Group 1	We don't need them for everyday jobs
Group 2	Some tasks are done so often, you know how to do them. It's not always that we take a print-out into the field.
Group 3	Routine tasks, even if there is an instruction, if we have done it maybe 20 times, we don't use it. Taking a filter out of service for example. It's not every shift that we bring out an instruction. It depends on how the plants are running. If it's only standard stuff, it can be a whole week without the need for an instruction.
Group 4	I would say, we don't use it for compressor startups and the likes, that don't take long, the date and time etc is not filled in. They are told to use the instruction, but we don't do it.
Code: 2 (Used/appreciated for infrequent/complex/new tasks) Theme: 5 (Signing off and writing comments during use)	
Group 1	It's mainly for infrequent jobs that we use the instructions…If I, for example, disconnect a gas tanker, something that's not done so often, I really check the instruction.
Group 2	We use instructions and fill in check lists every day. Some tasks, that you do seldom, that's when you bring out the instruction. Some tasks have to be done in a certain order, a plant shutdown or startup for example. Then it's a must to have an instruction, to follow the stages.
Group 3	It depends on how often we do jobs that require an instruction. A few times per month perhaps. Large jobs. A boiler shutdown or startup, large or critical pumps, more complicated and less often. It's not easy if one has to do a task maybe every second or forth or fifth year. It's hard to remember and explaining for someone else then is very difficult.
Group 4	
Code: 2a (But sign-off and comments can be poor sometimes) Theme: 5 (Signing off and writing comments during use)	
Group 1	It can say, "completed to step 7". Do they mean that step 7 is completed? Then you have to go and check anyway.
Group 2	It's happened to me a few times that steps have not been signed off, and no hand-over information either. Then I have to check with the outside operator what's been done…Those are the worst jobs, just running around to double-check.
Group 3	
Group 4	We are quite strict about sign-offs (during plant startups)...if it's not signed you have to go back and check and then sign. But then, the last few steps can be a bit... It can be fluffy items like "during the whole start-up, check that there are no leaks"".
Code: 2c (Operations engineers can prescribe use of an instruction) Theme 4 (When and why are they used (or not))	
Group 1	
Group 2	Often, engineer's operational requests make reference to an instruction.
Group 3	

Group 4	Before a plant start-up, I bring the instruction to the control room, it says "master" and it has to be filled-in and returned to the operations engineer when completed. In other cases, start of a compressor or something, I don't have to hand out a printed copy, with a master in the control room, the shift does that. We have never said anything, or I haven't even thought about, it being a requirement, with archiving and the lot. But I have told my people, if the procedure goes across the shift change, they have to fill it in. When the person who starts signing off the instruction does it correctly, it has a tendency to continue. Especially when (the engineers) hand over a startup instruction, and it's signed off, we have checked alarms and all those things (preconditions), then take it to the shift manager who fills in his items. Then, when it's taken to the control room, as a master, it's difficult when it's properly done from the start, to start being careless.
Code: 3 (Updating is cumbersome and/or slow **Theme: 1 (Writing and updating)**	
Group 1	
Group 2	The problem is that it takes time to get a change done. First it has to be written down, then reviewed and then approved and published. It's a messy system too, so people get fed up. You don't bother to make a comment, it's too much work. You can send an email to the operations engineer and get a reply, "do it yourself".
Group 3	We can complain (about anomalies) in instructions, and it might not be taken further…It's never changed…
Group 4	When you haven't worked with it (the document system) for some time, it get's hard, things are spinning around in those work flows. You have to update every 5 years, then you get the same pile again. I got hundreds of emails (automatic reminders) from NN (the system administrator). I have never met that person, but it's not someone I like a lot. Someone in IT decided to get this (document system), and "smack", it was implemented in the whole company. It's not very user friendly. When you get used, it's not that bad. But when Word is involved, funny things happen. When existing instructions were migrated, some got the date when they were approved in the old system, some got the date of the migration. Responsible author is a person, not a role, so suddenly instructions disappear in cyber space. One can lose documents completely...It happened two months ago; it (the system) has taken away the whole instruction. Now it's gone, we must rewrite it. The problem is that there are large variations in the amount of interest, in the template, Word, writing instructions and computer literacy. It takes a lot of time, even for me who likes it, an instruction can take 2 days to transfer to the new template, even if I don't change a single item (in the actions).
Code 4 (Can be ambiguous (e.g., lacking detailed information)) **Theme 2 (Format and style)**	
Group 1	
Group 2	Steps can be in the wrong order. A sampling instruction was so advanced, more or less impossible to follow. When the engineer was asked to demonstrate, he could not do it. They have changed it now.

Group 3	Almost every time when we use an instruction, there is something that raises a question…It's not necessarily a fault, it can be something that is not applicable, that's almost every other time. It is quite often, I think (that an instruction is difficult/impractical to follow). Yes, that happens, especially in a long instruction, there is surely something that is out-dated or something.
Group 4	
Code 5 (Not always updated) **Theme 1 (Writing and updating)**	
Group 1	A lot needs updating, there are new products, new blending operations, new equipment and piping…A lot of hyperlinks that you used to click on were not working.
Group 2	Instructions that are not updated can be a problem. Old instructions that are left as is year after year.
Group 3	When we started to update (some instructions), we sometimes found that equipment no longer exists, even though the instructions had been updated several times. The question is, how thorough?
Group 4	
Code 6 (Shift change challenges) **Theme 5 (Signing off and writing comments during use)**	
Group 1	If the shifts are responsible for a job that takes several days, we hand over to the the next shift and then they hand over to the next, and when we come back, I might be on another position… that's when the errors occur.
Group 2	The worst can be when you start a new shift, you might get a hand-over that "we are at step 27", but 24, 23, 22 might not be ready.
Group 3	
Group 4	I say it's useful (signatures and comments in instruction's checklists), if you're not ready at the end of the shift, the new shift will know where they are. Otherwise, one must go back and check what has really been done, as handovers is less than good at times. They are in a hurry to go home.
Code 7 (Control room vs plant coordination) **Theme 5 (Signing off and writing comments during use)**	
Group 1	
Group 2	Mostly during start-ups and shutdowns, the control room operator has a "master", where we sign off steps that are completed or under way. A problem that I have seen is that the outside operators don't have access to that. It's up to the control room operator to guide the outside operators. It would be better if everyone had access to the same copy (the "master").
Group 3	
Group 4	
Code 8 (Adaptations occur (can even be necessary) (normally after review/approval by shift supervisor/shift manager/op. engineer)) **Theme 6 (Authorized deviations ("adaptations"))**	
Group 1	
Group 2	One gets into situations that doesn't really fit the instruction, then we have to discuss, how to make it safe anyway. (About the work permit procedure)
Group 3	In the control room sometimes, some operating modes are not quite what's described in the instruction. It can be difficult to know whether to start in the middle of the instruction, or if that is just a similar operating mode. We have to talk together, the colleagues.

	If there is an instruction that is not possible to follow, at least on our shift, we discuss everything before deviating, and we might ask the area shift manager, "can we do like this". There are isolations (for maintenance) that are not keeping tight, in the end you have to try alternatives. They can be more or less discussed, but often it has been discussed, sometimes for several days, so many people might be involved.
Group 4	Us who work shift, we sometimes deviate from instructions, but there is a dialogue before we do it. Operators don't have any mandate to approve deviations from instructions. Shift managers do. It's partly to avoid calling the operations engineer in the middle of the night, or on the weekend. It's a mandate to do the best thing. Most deviations (adaptations) are about the order of different steps in a startup, or a shutdown. If we are deviating, it's not just I (as shift manager) who says, "do this", I discuss it with the area shift managers, even if it's not like a documented risk analysis. I don't know how clear it is, in writing, but the ambition is that the area shift manager is not allowed to do it (deviate) alone, you must involve the shift manager. When we talk about startups and things like that, when the shift manager and area shift manager decide together about deviations, it's not so much that a step in the instruction is impossible to follow, it's that we are in a situation that is not really covered in the instructions. They are large and complex plants; things happen that can't be foreseen. You can't write an instruction that covers all possible cases, you're stuck in the middle, a decision must be taken, and it's usually done by the shift managers. It's not often that the engineer on call is called, it's usually solved on-site by the shift, and I don't think that there are accident risks involved most of the time.
Code: 9 (Unauthorized/undesirable deviations/violations occur) **Theme: 7 (Un-authorised deviation (" violations")**	
Group 1	I think that we deviate from that instruction very often…the feeling we at the bottom have, is that there are so many documents, produced at the desk level. Can we at this level do the job in that way? Doubtful…We don't follow all the rules when we drain a tank, it's up to me if I go to the fire station to get a mask before draining, to protect against the fumes...I think they (management) knows about it (deviations), they would have to.
Group 2	During night shifts, we should check that stand-by pumps are kept warm, otherwise you might get a leak if they cut-in. The routine says it should be checked every night, but it's quite often that I find cold pumps. Could be that operators are tired during nights, or laziness. If we follow the instruction and drain with cold gas oil before draining, it will plug. If we open the drain a bit when it's still warm gas oil, things will work in practice, but you can't write that in the instruction. Unless the drain is drawn to a different sewer. It would be better to insulate and trace the drain. To drain the Merox tower, we should first drain to a vessel, then pressurize that and let down to storage tank. Instead, you can drain straight to tank. There are little things like that. It's not better, but with some instructions, things can be done quicker. You can't teach new operators such things, you learn it by yourself. There are probably many places, where there is no difference in safety, but the instruction is a bit inefficient, even if it works.
Group 3	When there is a recurring problem, you get used to handling that problem, and that can mean deviating from an instruction.

	It can be fire alarms for example, or gas detectors, alarming every now and then. We can't take it seriously every time…we can't call the fire brigade every time. If you try to follow instructions very thoroughly, you can be seen as difficult, for taking too long. Someone on a different shift doesn't bother with some steps, things will go faster for them. That's quite often. For example, when taking a pump into service, the temperature should be increased with 50 degrees per hour, nobody follows that, it would take...maybe 8 hours and nobody would accept that.
Group 4	If they don't know (what the instruction says). They think that they are doing things correctly. Before there used to be many instructions that people didn't care about, they were not considered necessary. People knew anyway. And sometimes they were not followed because they were not updated, or difficult or impossible to follow. Bypasses (of safety functions) are activated, but usually they (control room operators) come and tell us quite promptly. There used to be a culture, no question about it, when shifting pumps, the first thing you did was bypassing the safety function, so that the furnace would not trip. Also, the plant (reliability) is better now, it's not the same need for bypasses. Something that I have noticed, is that sometimes things happen with very experienced operators...a beginner hardly ever makes a mistake, (but) it may take a long time to do it (a task).
Code: 10 (Team work to reduce errors) Theme: 6 (Controlled/authorized deviations ("adaptations"))	
Group 1	
Group 2	What we often do nowadays is to work two together when (e.g.) shutting down and isolating a pump. If it's larger jobs, like a compressor, we might even be three. Shifting pumps is not that complicated, you might make an error once in a million, but it's done many times, so it's good to be two. But during low manning (e.g., summer holiday season), then you do it yourself.
Group 3	
Group 4	
Code: 11 (Managers'/supervisors' support varies) Theme: 6 (Controlled/authorized deviations ("adaptations"))	
Group 1	
Group 2	
Group 3	(When discussing procedure) the area shift managers, at least ours, are helpful. They have been operators in the past, and operated these units, and know what we talk about.
Group 4	
Code: 12 (Generally "low-blame" when errors/violations/incidents occur) Theme: 8 (Fear of failure (or blame))	
Group 1	Generally, we don't get hanged if we make errors, because everyone does them, more or less, and usually it's not so serious. Sometimes it costs a hell of a lot, but so what, if nobody is killed or injured.
Group 2	As long as you know what you're doing, it's ok. One should not take risks.
Group 3	If something goes wrong, somebody will ask, why did you not do this, or why did you not nitrogen purge for as long as it said (in the instruction). It's hard to say then, that he (the area shift manager) said. It's not written down and it's impossible to prove.
Group 4	We have not set an example ever, as far as I can remember, against people who don't follow instructions. Maybe some time that I'm not aware of.
Code: 13 (Difficulties finding an instruction)	

Theme: 9 (Finding an instruction (or not))	
Group 1	When you search for an instruction, you don't always get the latest version…Some operating type instructions appear in the product information manual. It's very difficult to find things in the management system... It was much easier before (in the old system) …Rather than taking the time to find it, I don't bother.
Group 2	
Group 3	Sometimes it can be difficult to find a certain instruction, you have to write exactly right when you search. Either the instruction number or the pump (equipment) number, and then it can matter whether you use a hyphen or not. I think the filter options (in the system) makes it easy, there is some clicking, but it's always possible to find, I think. If there is an instruction that you don't know if it exists or not, it would be good if the search is not so specific.
Group 4	When we transferred all the instructions to the management (document) system, for better and worse, it became difficult to find things. It's a bit better now but it's still a problem, when we know about an instruction, we may even know the name, but we have to spend an hour to find it. Those who seldom look at instructions, they may also find it difficult to find them. it's not just that they think that they know it (the instructions), they also think it's easier to do things without having to use the computer. There is a training need there. The instructions are not in a certain place, they are just tagged. If you make a spelling mistake and don't find an instruction for the equipment I'm searching for, you don't know where to start looking...even for me who is interested and understand a lot about these things. For those who don't, it's even more of a hindrance.
Code: 14 (Operator involvement in writing/updating) **Theme: 1 (Writing and updating)**	
Group 1	We tell the area shift manager, and he sends an email (to the operations engineer). Then, if anything is done, I'm not sure…An experienced operator could give input to the Area Shift Manager, but we don't have the time to sit down and write instructions, unless you are relieved of the normal work...It should be the operations engineer, and in this place, they have usually started as an operator and built-up local knowledge.
Group 2	Operators can assist in making an update, but we have not received any training about the system. I have sent emails to the operations engineer, but the instructions have not been changed. The reply is often: "do it yourself". Some of us have edited instructions with proposed updates. The way I see it, changing an instruction should be done by the engineer. They have written most of it from the start. Why should we do it? We can tell them what to write. Or it should be easier to edit and send for review and approval.
Group 3	We (2 operators) have worked a lot with updating (and transferring instructions to the new template). A lot of things that we were not sure about, then we have asked: Is this really right? Or. if we did it this way, maybe it would have worked better?
Group 4	Operators on one shift are migrating instructions to the new template, then the area shift managers review, and then I (engineer) review before it goes to the area operations manager for approval. That way 3-4 persons on each shift, 15 in total

	can do the work (of keeping instructions updated on one area), instead of just 3. So, we make progress there too.
Code: 15 (Sometimes an instruction is partly applicable) **Theme: 2 (Format and style)**	
Group 1	
Group 2	When we had the fire in 2018, two furnaces were operating, that's different. The instruction was for shifting furnaces, not for going from two to one. (You had to take applicable parts?). Go down (in the instruction) and see what it looks like.
Group 3	
Group 4	
Code: 16 (Lack of information about new/updated instructions) **Theme: 3 (Information and training)**	
Group 1	It would be great, if we sat down and read new instructions, and checked in the field if they are workable. But we are not there today.
Group 2	
Group 3	We don't get information (about changes), we just see it in the system. That's how I experience it. At one stage, one got an email about an update, with a link to the instruction, with the changes underlined. That was great. But it didn't last for long. No, you must read all of it and think, what have they done now.
Group 4	For some instructions, we write in the operational requests, that an instruction is updated, e.g., if the maximum temperature in a reactor has been increased, then we usually write it there. Otherwise, we mention it in the weekly department (with area staff) meeting minutes. We may have slipped, things have been hectic recently, so maybe it's not mentioned. It's (real) changes that should be mentioned. That has worked quite well, I think. If it's a startup instruction to be used during the turn-around in 2022, we don't have to say that. They will se it when they print it at that time. One looks at the approval date, then you see if something has happened or not. That's something good about the new template, that the latest revisions are listed. That's a good thing, as it's mentioned at the top. We (the area shift managers) are instructed by the operations manager to go through the meeting minutes, and all the updated instructions should be mentioned there. We should inform the shift about those. However, instructions from other departments (e.g., HSEQ) never gets communicated to us (shift managers). They are difficult to find in the system too.
Code: 16a (Little focus on instructions during training/re-training) **Theme: 3 (Information and training)**	
Group 1	You work with an older experienced operator who shows you the job. There are instructions, but they might not be updated.
Group 2	One is often trained by someone with experience, and he thinks in one way, then you work with someone who thinks in a different way.
Group 3	
Group 4	When one is telling or explaining something to a new operator, and bring the instruction, I used to say, "this is not how we usually do it, but this time we'll do it". That sounds really strange, I can't say that.
Code: 17 (Production pressure, goal conflicts) **Theme: 7 (Un-controlled/un-authorised deviations (" violations"))**	
Group 1	It's not unusual that we are asked to shut down and isolate equipment towards the end of the night shift, so that maintenance can start at 7 am. That can be stressful.
Group 2	

Group 3	One hurries too much. Pressure from the area shift managers or the engineers. One has to speed up. When there is an outage, there is lots of talk about starting up, then it feels like things are not so strict. I agree...The limits are stretched more, the longer it takes. During plant startups, there are some tricks that can be used to make it go faster and easier. If you follow the instruction, they are not allowed, but others do it and get the plant going, and then they are praised. We say that things (preparing work permits) should be allowed sufficient time, but then engineers come and say, "we have to get things going now".
Group 4	When you are taking equipment out of service, and there is time pressure, or if you deviate in order to finish something, I feel that's where the larger risks are, where accidents occur. It can appear to be minor deviations… I can imagine, if there is a time when a pump should be ready for maintenance, people do their utmost to be ready in time. Then the risk of deviations is greater. There has been a lot of pressure on Area 1, things should be ready by 7 am, they (maintenance people) will be waiting then...You may have to start at 4 am... you are not such a good worker at 4 am.
Code: 18 (Views about Model 1 and Model 2) **Theme: (When and why are operating instructions used (or not))**	
Group 1	
Group 2	I think we should have a combination between Model 1 and Model 2. When you (e.g.) change crudes, you really want a good instruction.
Group 3	It's difficult to say, both Model 1 and Model 2 is there, perhaps somewhere in the middle. When we get new equipment, we are totally dependent on Model 2, there is never any instruction for new equipment, it's up to us to solve the task and then the instruction can be written. It's not really that we have a philosophy to be Model 2, it's rather that not enough time is spent on producing good instructions. It depends on how long you have been employed, in this group many are quite new, off course they need some support. Others, who have worked for 30 years, can manage in a different way.
Group 4	
Code: 19 (Various factors affect need for procedures, e.g., infrequent or complex tasks, experience and training, tiredness, shift changes) **Theme: (When and why are operating instructions used (or not))**	
Group 1	
Group 2	
Group 3	
Group 4	
Code: 20 (Can instructions promote dangerous "working without thinking") **Theme: 3 (Information and training)**	
Group 1	
Group 2	Model 1 seems more "robot-like"
Group 3	
Group 4	
Code: 21 (Adaptation when instructions don't exist or are not fully applicable) **Theme: 6 (Controlled/authorized deviations ("adaptations"))**	
Group 1	
Group 2	

Group 3	
Group 4	
Code: 22 (Unrealistic demands on operators) **Theme: 6 (Controlled/authorized deviations ("adaptations"))**	
Group 1	
Group 2	There are lots of circumstances each time you use a procedure, it can be in the middle of the night, you could have had a lack of sleep. The ability to think good each time might be affected. Model 2 demands work skills and advanced thinking, but we are recruiting new people and it can take several years to acquire the type of work skills that this industry demands.
Group 3	
Group 4	
Code: 23 (The need for detail depends on level of experience) **Theme: 2 (Format and style)**	
Group 1	
Group 2	Instructions can be written for the very experienced. With a few words the operator knows how to do. Instead of writing more specifically what to do and why. We often say that an instruction should be clear enough so that a beginner can follow it. But some conservative people say, if it's just to follow step by step, the operator will not understand and think, just do the steps. Someone who has been here since 2013, might not have experienced a plant startup. It could be 8 years in between. And even if he has process operations experience, he may not know how it's done on that unit. Someone who has been here 40 years, when starting a compressor, it can be 5 years since he worked on that unit, so he won't know about it.
Group 3	(Instructions for routine tasks) can be useful, especially for new people. Once you have learned, they disappear by themselves. It can depend on who you are trained by. You may be more or less dependent on instructions.
Group 4	
Code: 24 (Inconsistent format and level of detail) **Theme: 2 (Format and style)**	
Group 1	
Group 2	It seems to be changing towards more detail. The instructions on the (new) vacuum unit are pretty detailed. (In an old instruction), it might say "nitrogen-flush the compressor twice", rather than "open that valve, open that valve" etc.
Group 3	Some instructions, many different people have written them, they are not the same, even if there is a template. So, some can be very good, some are not so good. Some go into detail a lot, that may not be necessary for some tasks. And some might skip those steps because we know them anyway. They write for those who have done it before. Some are written so that anybody can do it from the start.
Group 4	It was said (during the migration to the new document system) that instructions should be written for people who did not know anything, everything was overly precise. She (the consultant) wrote an instruction, but she didn't understand, so he (an engineer) did it in a way that she could understand.

	You should be able to take someone from the street and say, "do this". But we don't work like that here, you have some education before you get inside the gates, and you get trained, before getting it (an instruction) in your hand. I think that's a misunderstanding. Everybody did not get that training. In the beginning, they (some instructions) became very detailed, but now it's more or less the old instructions copied into the new template. Maybe we should have been clearer in SHB 05 (section handbook, chapter about e.g., format of instructions), how to use the first part of the template and what to expect of different instructions, so that they don't get too long.
Code: 25 (Potential advantages and disadvantages with new template) **Theme: 2 (Format and style)**	
Group 1	I look for the "do this, do that". I don't pay much attention to the hazard pictograms.
Group 2	It's more precise about preconditions, hazards etc. That's good.
Group 3	It's good, easier to get an overview, clearer. It's probably good to harmonize a bit. Another good thing with the new template is the safety information in the beginning. Whether you check it..., but it's good that it's there. We write a lot of comments too, why we do things. Also, pictures, for example where to put a pressure gauge. If there is a picture, you know exactly where to put it. That (the headings highlighted in yellow) depends on whether you're starting up a whole plant, or taking a part out of service, the complexity and handling is rather different. The title tells you what it is about, but a start-up, with so many steps, it could be useful.
Group 4	It's perceived as rather cumbersome, there are very many pages to print, for no good reason if you ask me. The main difference is that every action should be a separate item. It should not say: "close the drain and open the inlet valve". It should be two items, one for each action. Then there are other things I think is so-so, like the hazard pictograms and things like that. Things that's not implemented, that we don't use etc. There is too much extra information, so you can't see what's important in the instruction. Like we were used to, pre-conditions came first. Now there is a table of contents, if it's a long instruction, then there is Aim, Scope, Safety and Risks, Environmental Aspects and Legal Aspects, things like that, and the hazard pictograms...There will be many pages to flick through before you get the real thing, sort of. Yes, but it's also how you use it. Some have used it quite well. I like the separation of actions very much, the sub-headings and comments about each new stage, followed by (say) 10 actions in that stage. I also like how the risks are mentioned, but you can't mention every risk in the refinery, then it becomes too heavy.
Code: 26 (Emergency procedures are used and useful) **Theme: 4 (When and why are they used (or not))**	
Group 1	
Group 2	Emergencies can affect the whole shift, then the shift manager or area shift manager usually come to the CCR with the emergency instruction. We often review them during annual emergency training.
Group 3	

Group 4	When we have handled an acute situation, we should sit down for an hour, and write instructions and blind lists and such. We are very bad at that…People want to hurry…get everything going as soon as possible…That's even more dangerous jobs, really.
Code: 27 (Problems with new/modified plants and equipment) **Theme: 1 (Writing and updating)**	
Group 1	A lot need to be updated. There are lots of new products, new ways of blending, new equipment and pipes.
Group 2	
Group 3	For new units, a workable instruction is often missing. Or, at least that it is not thought through.
Group 4	
Code: 28 (The work permit procedure is demanding) **Theme: 7 (Un-controlled/un-authorised deviations (" violations"))**	
Group 1	
Group 2	A hot work with open flame can perhaps not start until 8 am. 4 persons have to inspect the workplace first; you have to find a time. It has become stricter. We have not had that many permits since the new instruction came. It may become more of a problem in the future, with the Synsat (construction) project. If we are not sure (about something in the updated instruction), we have the area shift manager and each other to discuss with.
Group 3	It's good with this procedure, that we try to harmonize, e.g., between the shifts. There are still some differences in the way of working, also between the areas.
Group 4	Where I see deviations, that's in the work permit procedures. (Permit issuing operators might say) "I have worked here for so long, I can de it in a better way". It's not often, but that's where I have heard about it (deviations). When we isolate equipment, it's very clear in the instruction, that we should place a plastic seal around the valves, so that they can't be operated without breaking the seal. For practical reasons, to simplify subsequent adjustments, people sometimes just hang the seal on the valve wheel. The alternative is to wait with the sealing until there is no need for further adjustment.
Code: 29 (Applicable instructions don't always exist) **Theme: 6 (Controlled/authorized deviations ("adaptations"))**	
Group 1	
Group 2	Often, engineer's operational requests refer to an instruction. If not, and I don't know what to do, I will have a dialogue with the area shift manager. We can call the engineer, or (at night) delay that job. That's not very common. Most of the time we try to find a solution, to get the job done. It depends, what job it is. If it's rather simple, we probably solve it, but because of things that have happened, the fire, release etc, we have become more aware of the risks if we don't have an instruction to follow.
Group 3	
Group 4	I was thinking about simple things, taking pumps out of service, or isolating a control valve. There are no instructions, it's normal skills. There are certain rules, you can't open a flange with following certain rules and procedures, but there is no operating instruction. Except on the (new) 840-unit, there are instructions for every pump, step by step which valve to operate. Before, the engineers' operational requests would just say "isolate that control valve" without mentioning hazards, e.g., H_2S. But nowadays, at last, the engineers' requests always start with safety.
Code: 30 (General attitudes has improved over years)	

Theme: (Un-controlled/un-authorised deviations (" violations"))	
Group 1	
Group 2	
Group 3	
Group 4	A few years ago, we (area operations managers) decided that "the new black" was to follow instructions. At first it was like a joke, but then we started to really explain why. Then we got back demands for instructions to be usable. We have not achieved 100%, but we are getting better at keeping instructions updated which also creates trust. Well, when it comes to Area 1... When I worked at the cracker (years ago), everything was about keeping the damn thing going for as long as possible. We did anything to avoid a shutdown. I remember (years ago) when you followed the experienced people..."following the instruction has never worked. I do it this way instead:"
Code: 31 (Recent/ongoing efforts to update and improve the instructions) Theme: 1 (Writing and updating)	
Group 1	
Group 2	Updating is getting better and better, the priority has increased.
Group 3	
Group 4	
Code: 32 (Improved completion of instruction checklists (filling in during use)) Theme: 5 (Signing off and writing comments during use)	
Group 1	
Group 2	
Group 3	
Group 4	We stress that if a check list item is not signed off by a previous shift, the next shift has to go back and check. If I get back a start-up instruction now, it's filled in to 100%, it's rare that something is missing on those long check lists.
Code: 33 (Reliance/dependence on shift managers/supervisors to initiate use) Theme: 4 (When and why are operating instructions used (or not)	
Group 1	I would not bring up that instruction, but hopefully the shift manager would do it.
Group 2	
Group 3	
Group 4	