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Improving the Management and Use of Operating Instructions for Process Safety

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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 to make progress on safety. Based on the findings, a framework was developed to illustrate some potentially useful practices regarding the management and use of operating instructions.

1. Introduction

This paper is based on a thesis by this author, at the master programme in human factors and system safety at Lund University. The project consisted of a literature review and a qualitative case study at a large process plant in Sweden. The objective was to get a better understanding of challenges and opportunities for improvements related to the management and use of operating instructions in the process industry.
The process industry, like other complex and high-risk industries, relies heavily on documented operating instructions for safe and reliable operations (Mannan, 2012). Problems with procedures are frequently implicated in accident investigations, including high-profile disasters like Piper Alpha, Texas City and Buncefield (Hopkins, 2011). Many high-risk industries are trying to improve compliance with procedures (Hale & Borys, 2013a). However, excessive proceduralization and focus on rule-following can be counter-productive, according to several writers (Bieder & Bourrier, 2013).
Sidney Dekker (2003) introduced the notion of two paradigms, Model 1 and Model 2, where Model 1 is authoritarian and inflexible, and Model 2 is consultative and flexible. Dekker and others (Hendricks and Peres, 2021) suggest that most organisations should move towards Model 2 to make progress on safety. However, systematic use of ideas from Model 2 has not been studied in practice in the process industry, at least not by rigorous research. Hence, this thesis project was considered useful.

2. Literature review

2.1 The case for procedures

Standardized and documented procedures are generally considered useful, or even necessary, in complex sociotechnical systems such as process plants (Hale & Borys, 2013a). The main reasons can be briefly summarized (Reason, 1997):

- tasks can be complicated and difficult to remember
- different actors need coordination
- a reference for training and monitoring
- as a form of 'organizational memory'

2.2 The problem with procedures

Violations can occur due to, e.g. (Hale & Borys, 2013a, p. 212):

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- 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

An excessive amount of detailed operating instructions and demands for compliance and accountability can be counterproductive (Bieder & Bourrier, 2013). Due to the complexity of process plants, "we cannot cover every possibility in our instructions and the longer we make them, the less likely they will be read." (Kletz & Amyotte, 2019). Furthermore, the willingness and capability to handle situations where instructions don't exist or don't work is impaired if people become too used to follow instructions, instead of using experience and tacit knowledge (Bergström et al, 2009). Fear of being held accountable for unintended consequences could also prevent people from taking own initiatives (Dekker, 2020).

2.3 Model 1 and Model 2

Sidney Dekker introduced the idea of two different paradigms in relation to procedures, Model 1 and Model 2. Model 1 is a classic Tayloristic approach, where engineers and managers write and issue rules and procedures that workers are requested to follow. In Model 2, "safety results from people being skilful at judging when (and when not) and how to adapt procedures to local circumstances" (Dekker, 2003, p. 235). Rules can produce good safety results, especially for common workplace accidents such as slips, trips, and falls (Hopkins, 2011). However, according to Dekker, some risks, especially in complex activities, are difficult or even impossible to prevent without fundamental changes towards Model 2.

2.4 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 still maintaining useful aspects of model 1, such as attention to detail, deference to expertise when required, and compliance with rules and procedures that make sense. The following steps are described as options within that 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.

2.5 An empirical study of Model 1 and Model 2 indicators

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, as well as outcome variables, such as "How many incidents have you been involved in in your career?" and "How often do you deviate from procedures for a highly hazardous task?" (Hendricks & Peres, 2021, p. 4). 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). According to the author's, the results provide support for Dekker's Model 2.

2.6 Conclusions from the literature review

This brief literature review has demonstrated some common problems related to procedures in safety critical domains. Some potentially useful approaches have 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).

3. Method

The main research data was gathered through focus group discussions with employees at a process plant, who are involved in writing, updating, and using operating instructions. Subsequent thematic analysis enabled the researcher to make some conclusions about the practical application of Model 1 and Model 2 theories.

3.1 The case

The plant is in Sweden. It consists of several highly integrated process units, tank farms and a harbour, divided into three physical and organisational 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 different operator tasks, published via a computer-based document management system (SharePoint application).

3.2 Document review

To prepare for the group discussions, and as a form of triangulation, some pertinent company documents were obtained and reviewed by the researcher. Company representatives assisted in selecting relevant documents. The types of documents were:

- Instructions for plant start-up
- Instruction for furnace mode change
- Instruction for abnormal situation
- Work permit procedures
- Incident investigations
- Process safety event statistics
- Safety climate questionnaire results
- Guideline for writing operating instructions
- Template for operating instructions

3.3 Group discussions

Group discussion ("focus groups") 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. A company representative assisted in selecting the informants, based on a mixture of purposive and convenience sampling. There was one meeting with 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 shift manager, 2 area shift managers, 3 operations engineers
4 persons (1 female, 3 males). Average of 15 years with the company (range 2–38 years).	6 persons (all male). Average of 16 years with the company (range 6–39 years).	6 persons (2 females, 4 males). Average of 8 years with the company (range 2–20 years).	9 persons (1 female, 8 males). Average of 24 years with the company (range 15–38).

Table 1 Focus Groups

A set of questions was prepared before the meetings, inspired by the literature review and the document review:

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

The informants were encouraged to discuss quite freely. All the questions were not spelled out exactly as listed but covered indirectly.

4. Findings and discussion

The framework shown in Figure 1 below was developed by the researcher, to show how the findings from the literature review and the case study can be applied in practise. 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)". The findings from the case study are discussed for each of the numbered boxes.

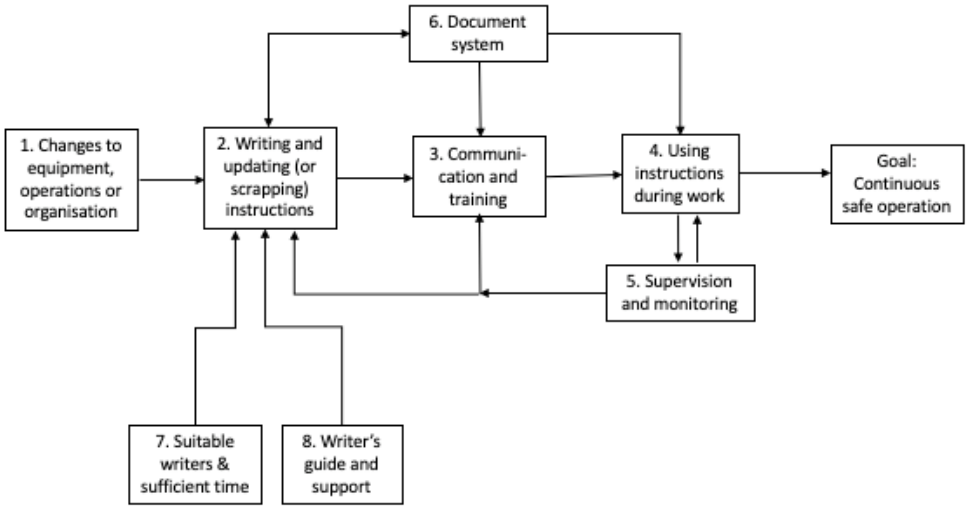

Figure 1: Framework for the management and use of operating instructions

4.1 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 92 new operating instructions. Furthermore, organisational changes mean that writers of instructions, and the operators affected by particular instructions, change from time to time, with implications for e.g., updating (4.2) and communication and training (4.3).

4.2 Communication and training

Instructions for plant shutdowns and start-up are reviewed in group sessions with operators prior to planned shutdowns and start-ups. Emergency instructions are practiced or discussed with operators annually. Training and information about the work permit procedure is conducted regularly. For straightforward routine tasks with relatively low risks, training is mainly on-the-job 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 instructions in the competence check-out procedures. Important changes in instructions seem to be 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.

4.3 Using instructions during work

Each unit is usually cold started only 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 therefore rely on the start-up instruction to take the right actions, and give the right instructions to the outside operators. 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 dynamic developments and practical issues. The start-up instructions are in a checklist format, where the control room operator must sign-off each step on a paper-based "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,

to give advice and directives to the operators. The outside operators often use 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 awareness of the situation, but rely on instructions from the control room operator. The operators at the case study plant are obliged to consult the area shift manager whenever they find a need to deviate from instructions. That makes sense, since one person alone can easily overlook an undesired effect of a deviation. As an alternative, in the spirit of Model 2, it might be possible to allow pairs of sufficiently competent operators to proceed with some deviations without prior approval from the area shift manager. In practice, that probably occurs every now and then, but it might be difficult to formalise.

4.4 Supervision and monitoring

Analysis of gaps between Work-As-Imagined and Work-As-Done (Hollnagel, 2014) can be used to improve instructions and their use. Systematic monitoring of compliance with operating instructions could be in the form of behaviour observations and audits. It has been shown that behaviour observation techniques can lead to improved compliance when it comes to rather simple and straightforward rules (Hopkins, 2011), but an authoritarian "top-down" style (Model 1) is considered counter-productive (Dekker, 2020). At the case study plant, operators, area shift managers, operating engineers and operating managers seem to be quite open and constructive in discussions about operational issues. Audits are conducted for some key procedures, such as work permits and isolations for maintenance, and by-passing of safety instrumented functions. 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 (Bieder & Bourrier, 2013). It makes sense when deficiencies in instructions are revealed by an investigation, but the effectiveness could be questionable, or even counter-productive, if changes in instructions are used only as a "quick fix" (Lundberg et al, 2010).

4.5 Document system

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 by Dahl (2013), who pointed also at the bad signal value of poor document system usability. Those who are involved in writing and updating instructions at the case study plant also had difficulties with system functions like document tagging, due date reminders and the review and approval automated work-flow. 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 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.

4.6 Suitable writers and sufficient time

In the case study plant, operations engineers have traditionally been responsible for writing and updating operating instructions. That makes sense since they are usually appointed based on prior experience and competence as operators and shift supervisors. Perhaps because they have that background, they may not bother to consult with operators about the best ways to operate. Furthermore, they are usually very busy people, torn between being out in the plant, attending meetings and acute problem solving. The ability to write well can also vary. Hence, the organisation seems to struggle somewhat 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 instructions in their area. When they finish a draft, it is sent to the area shift manager and the operations engineers for review, and perhaps 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.

4.7 Writer's guide and support

An idea discussed with one of the informants would be to appoint a 'writing coach', someone with an operations background and some interest in and talent for writing good instructions. He or she could develop the existing guideline for the format and style of operating instructions, rewrite some instructions as good examples, identify instructions that need extra work, and assist writers with advice and comments on drafts. He or she should spend some time reading relevant literature, or perhaps take part in formal training, about human factors and procedures.

5. Conclusions

Organizations should continue to invest in the development of operating instructions, especially for safety critical tasks, and encourage operators to use them. Model 2 theories are indeed useful, to improve the quality and use of instructions. The framework proposed by the researcher supports such developments. Key activities are:

- Monitoring and follow-up of gaps between work-as-done and work-as-imagined
- Involvement of operators in the development of instructions
- Training in the interpretation and adaptation of instructions

While operator involvement is essential, operations engineers are still appropriate 'owners' of the instructions. Appointment of a talented 'writing coach', and development of an internal 'writer's guide' seem worthwhile, to develop and maintain an appropriate format and style. Future research to test the effects of such initiatives seems warranted.

Generalisability and transferability cannot be claimed based on a case study of one plant. However, based on the literature review and the researcher's experience from the process industry, these conclusions might well be valid for most process plants.

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