Effective Shift Handover

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Abstract. In the refining industry, control room and field operators document their daily activities using shift logs. These logs are supposed to be an important part of the shift handover process and are the mechanism by which activities are coordinated across shifts. Previous research identified the need for a more structured approach to shift handover. However, the value of a structured approach has never been demonstrated experimentally. We report here on an experiment sponsored by the Abnormal Situation Management Consortium conducted at the ENGEN Refinery that compared the quality of shift handovers using a structured checklist-integrated logbook to a more traditional less structured logging approach. The results showed that significant benefits to situation awareness derive from the more structured approach.

Keywords: logbook, shift work, shift handover, process control, situation awareness

1 Introduction

Early research found that communication is one of the factors that affects abnormal situation management in the continuous process industries [1]. Information exchange between shifts is a particularly critical failure mode. Information in shift logs often is limited in usefulness by a lack of structure and poor legibility and as a result white boards, post-it notes, and change sheets are common ways of enhancing communicating and coordinating across shifts [2]. However, many of these communication mechanisms suffer from a lack of structure and permanence. Laberge, et al. [3] conducted an extensive study of requirements for effective electronic shift logs. They reviewed current logging practices in industry, user cases, and failure modes, and recommended a series of best practices for logging and shift handover. The top recommended best practice was to improve the structure of the shift handover process using structured shift logs. Hence, the Abnormal Situation Management (ASM®) Consortium (www.asmconsortium.org) funded a research project to investigate the impact that structured shift logging material has on shift handover effectiveness.

Several industrial incidents also emphasize the importance of effective logging and shift handover. On July 6, 1988, a large fire and explosion on the Piper Alpha offshore platform killed 165 and destroyed the facility. In his investigation, Cullen [4] identified several root causes and recommendations. Notably, a relief valve was removed for service and a blank had been loosely installed in its place. This information was not recorded in the control room or maintenance logs. During shift handover, the status of the pump work was discussed, but no mention was made of the relief valve work. Upon restart, the pump leaked, producing a flammable hydrocarbon cloud.

A more recent incident occurred at a BP refinery in Texas City on March 23, 2005 [5]. Fifteen people were killed and over 170 harmed as the result of a fire and explosion on the isomerization unit. The explosion occurred when a flammable vapor cloud formed following liquid overflow from the blowdown stack during operation of the raffinate splitter. The report noted several root causes, including a failure to log information and an informal and unstructured shift handover process. Both failures were contributing factors to the incident.

Collectively, the incidents and previous field research suggests that there is a need for a more efficient way to guarantee that the next shift gets the information needed for shared situation awareness. Research in other industries also suggests that better structure and organization are keys to more effective logging and shift handovers. Parke and Kanki [6] investigated the causes of documented aircraft incidents that could be traced to maintenance defects caused by a failure to communicate critical information at shift handover. A major conclusion was that face-to-face handovers are essential, but they are even better if they are supported by structured written material. They suggested a checklist of items be used to structure the shift handover. Their rationale was that written material introduces a certain redundancy in the otherwise completely verbal handover which reduces the possibility for errors in communication [7]. Parke and Kanki also point out that structuring the handover around a written checklist forces the organization to specify ahead of time the most important items of situational information for their particular operation, those items that should never be left out of the handover communication. Face-to-face shift handovers with written support have also been shown to reduce errors in aviation maintenance compared to strictly written handovers with all verbal communication filtered through a supervisor [8]. Face-to-face turnovers with written support are standard operating procedures in many high-risk domains, such as U. S. nuclear power plants [9].

In summary, there is strong direction in the literature to structure verbal face-to-face shift handovers around checklist-style written documentation. However, the effectiveness of such an approach to handover has been only anecdotally and analytically demonstrated in the process industries. An empirical, experimental validation of the approach is missing from the literature. This is particularly the case for the industrial process domain where shift handover research has been based primarily on interviews and observation. The present research was motivated by the need to quantify the extent to which shift handover effectiveness can be increased by structuring the verbal shift handover communication around a structured checklist-style written logbook.

2. Experiment Design and Method

A structured shift handover experiment was designed to test the following hypothesis. Using an integrated checklist and logbook to structure the shift handover instead of a less structured logbook will result in:

- A higher percentage of key events and process unit information being communicated during a shift handover.
- An increase in the situation understanding by the second shift operator as he or she takes over control of the unit.

2.1 Within Groups Design

Figure 1 below illustrates the Within Groups experimental design used to compare shift handover performance under each of the two different logbook conditions. Control room operators were assigned to work in pairs. There were two trials, A and B. Trial A always presented the less structured standard logbook condition and Trial B the highly structured checklist-integrated logbook condition. This arrangement of conditions was intended to eliminate any learning effects that would naturally arise if conditions were randomly assigned to either Trial A or Trial B. In other words, we were concerned that if the checklist-integrated logbook were used in Trial A, then shift handover performance with the conventional less structured logbook might appear to be better than it really was. Also, we expected negligible practice effects because shift handover is such a common activity for the experienced operators who were our subjects. So we opted for fixing the order of the two conditions. One of the operators from each pair was randomly assigned to begin Trial A. He/she completed the first half of the incident scenario, resulting in a unit shutdown and then completed a shift handover to the second operator in the pair who took over, executed a unit start-up and completed the scenario. The two operators then switched roles. The second operator completed the first half of a second, different incident scenario, also resulting in a unit shutdown. He/she then completed a shift handover to the first operator who executed a unit startup and completed the second scenario. Thus, each pair of operators completed two shift handovers and in the analysis, the pairs were treated as single entities which completed both structured and unstructured experimental conditions, rather than two individuals, creating the Within Groups design. There were also two scenarios which, for each pair of operators, were counter-balanced across Trials A and Trial B.

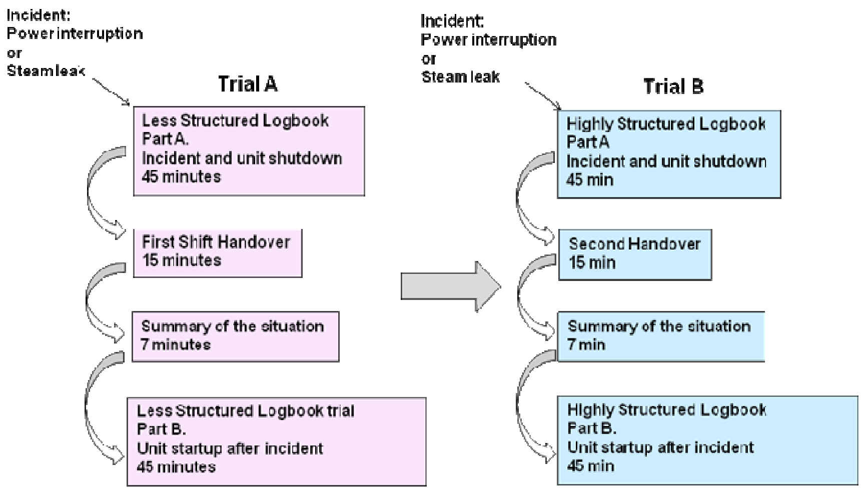

Figure 1. Block diagram of experimental protocol.

2.2 Experiment Method

The experiment was conducted at the ENGEN Refinery (a division of Engen Petroleum Ltd.) in Durban, South Africa. Two versions of the shift handover logbook were evaluated. One was the then current less structured logbook in use at Engen's Durban refinery, which featured general headings like "Safety", "Environment" and "Equipment" We deem this as being "less-structured" as the logbook did not specify the details that should be documented, and thus it was up to the outgoing shift operator to decide what should be logged.

The other was an experimental logbook designed around a shift handover checklist developed by an ASM member company based on recommendations from the research on requirements for effective electronic shift logs [3]. Separate from the logbook, the checklist provided details which operators were required to convey during handovers. If a particular section was irrelevant, the operator was required to acknowledge that there was nothing to report under that topic. The experimental logbook design integrated this checklist, resulting in specific sub-headings which the operators had to consider before recording details. We refer to it as the "checklist-integrated" logbook because its headings /categories of information correspond exactly to those used in the ASM member company checklist.

For the experiment, both versions of the logbook were provided electronically to the operators using the Honeywell OMProLog. Both versions of the logbook were considered to be similar in length, as the contents that are to be documented in both versions were identical. That is to say, there were no "missing headings" in the less-structured logbook compared to the checklist-integrated logbook which would otherwise have resulted in intentional omission of detail. This was verified by comparing model logbook entries written by two senior operations engineers who helped in the experiment development. As part of ENGEN's standard operating procedures, the completed logs were printed out to be filed, and the operators were encouraged to use the printed logs during their handovers.

A Honeywell high-fidelity process simulator running the Advanced Distillation Unit Operations Standard Model provided the experimental platform. This model provides a comprehensive and dynamic simulation of typical distillation columns used in gas recovery plants common to most refinery and petrochemical sites. Two failure scenarios were scripted and presented via the simulator:

- Power Interruption- A power interruption occurs, causing pump and fan outage and low tower level alarm, and forcing a unit shutdown
- Steam Line Rupture- A steam line rupture occurs, causing loss of heating steam and forcing a unit shutdown

The events of each scenario were designed to include at least one instance of each information category in the checklist-integrated logbook. The scenario events thus generated a significant number of key items of information that had to be communicated during the shift handover and that affected unit startup during the second shift. Some additional events, not related specifically to the checklist, were included in the scenarios to serve as distractions. Also, the scenarios were designed to force a significant amount of interaction between the console operator, field operators, supervisor, and other plant workers. The field operators, supervisor, and other plant workers were role-played by senior operations engineers from the Engen refinery. They communicated with the console operators during the experimental sessions via radio and mobile phone.

Study participants were operations personnel from the ENGEN Refinery, a division of Engen Petroleum Ltd., in Durban, South Africa. The median age of participants in the study was 39.5 years (range = 27 to 62 years). The median years of DCS experience was 6.5 years (range = 1 to 25 years) and median years in operations was 20.35 years (range = 6 to 35 years). In order to balance the influence of the experienced operator over the inexperienced one, an attempt was made to pair operators that had equivalent experience.

Ten pairs of operators each participated in one 3-hour evaluation session. Each member of the pair had the opportunity to serve as console operator for the first shift one time and as the console operator for second shift one time. As first-shift operator, each member of the pair was responsible for: 1) conducting a failure response and unit shutdown, and 2) preparing and presenting a shift handover. As second-shift operator, each member of the pair was responsible for: 1) understanding the situation at handover, and 2) using that information to conduct a unit startup at the appropriate time. Logbook quality, and second-shift operator recall of situational information were taken as measures of shift handover effectiveness. Operator recall was measured immediately following handover and at various times during the second shift.

3 Results

3.1 Summary of Findings

The results of the experiment supported the hypothesis that using an integrated checklist and logbook to structure the shift handover, instead of a less structured logbook, will increase shift handover effectiveness. Specifically, we found that using the checklist logbook resulted in the following:

- A higher percentage of key events and situational information were documented by the first-shift operator who used the checklist logbook compared to a less structured logbook.
- The second-shift operators who experienced the structured shift handover using a checklist logbook showed an increased understanding of the situation they inherited from the first shift compared to those who experienced a less structured handover.
- The second-shift operators recalled a higher percentage of key items of situational information immediately after shift handover and responded correctly to a higher percentage of probe questions during their shift.
- The above benefits appeared to come at the cost of slightly longer handover times.

3.2 Analysis

The experiment generated a raw score for each team on each of four performance measures (logbook quality, recall, probe responses, and time) for each of the two scenarios. For analysis purposes the raw scores for logbook quality, recall, and probe responses were normalized to percent correct out of the total possible responses. The statistical results reported here used these normalized scores as a way to deal with the fact that the scenarios, which had slightly different numbers of reportable events, were counter-balanced across the two shift handover conditions. Also, all the analyses reported below were exploratory and more liberal statistical significance alpha values and one-tailed directional tests were used [10][1].

Quality of the Logbook. Quality of the logbook was assessed post hoc by reviewing log entries and scoring them against a model logbook generated by operations experts at the ENGEN Refinery. The model logbook represented the information items that the expert would expect in a high quality logbook report for each of the two scenarios used in the experiment. Table 1 shows that the percentage of the total expected information items entered in the logbook was significantly greater for operators who used the Checklist- Logbook than those who used a less structured logbook, $F(1, 9) = 6.80$, $p < 0.02$ (one-tailed).

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[1] Significant alpha values were set at $p < .10$ but marginally significant results ($p < .15$) were also noted.

Table 1. Performance summary for logbook quality.

Shift Handover Approach	Mean Percent of Total Items Expected	Standard Deviation	% Change
Checklist-Integrated Logbook	76.11	10.48	+18.63%
Less Structured Logbook	57.48	17.64	

Ability to Recall Situational Details. A successful shift handover must ensure that the second-shift operator leaves the briefing with a mental model of the situation that is complete, accurate and consistent with the key events that occurred during the first shift. The second-shift operator's ability to recall situational details from the first shift following shift handover was taken as a measure of accuracy and completeness of the second-shift operator's mental model. Table 2 shows a trend toward more complete recall following shift handover among second shift operators that used the Checklist- Logbook compared to operators who experienced shift handover using the less structured logbook , $F(1,9) = 2.93$, $p = 0.12$ (one-tailed).

Table 2. Summary of second-shift operator ability to recall first-shift situational information.

Shift Handover Approach	Mean Percent of Total Items Recalled	Standard Deviation	% Change
Checklist-Integrated Logbook	51.06	16.24	+8.96%
Unstructured Logbook	42.10	10.34	

Ability to Respond Correctly to Probes. As a further measure of the effectiveness of shift handover communication, second-shift operators were asked a series of probe questions as they worked at starting up the distillation unit. The probes generally requested updates or status of events that had their start or roots in the first shift. Table 3 shows a trend among operators who had experienced a shift handover using the highly structured Checklist Logbook to respond correctly to a higher percentage of probe questions than those who had been briefed with a less structured logbook, $F(1,9) = 3.06$, $p = 0.11$ (one-tailed).

Table 3. Summary of second-shift operator ability to respond correctly to probe questions about the first-shift operations.

Shift Handover Approach	Mean Percent of Total Probes Responded to Correctly	Standard Deviation	% Change
Checklist-Integrated Logbook	56.43	18.06	+7.86%
Less Structured Logbook	48.57	16.02	

Shift Handover Duration. One of the interesting questions is whether or not using a structured approach to shift handover, such as briefing from the Checklist-Logbook, was more time-consuming than using a less structured briefing approach. Table 4 shows that shift handovers using the Checklist- Logbook took slightly, but not significantly longer than using the less structured shift handovers, $F(1, 9) = 2.74$, $p = 0.13$.

Table 4. Summary and comparison of shift handover duration using the Checklist Logbook to handover using a less structured logbook.

Shift Handover Approach	Mean Duration of Shift Handover (in seconds)	Standard Deviation	% Change
Checklist-Integrated Logbook	323.90	80.95	+15.84%
Less Structured Logbook	279.60	90.59	

4. Conclusion and Recommendations

This experiment investigated how the effectiveness of shift handover can be influenced by imposing more structure in the form of a logbook organized around a shift handover checklist. Logbook quality, and second-shift operator recall of situational information immediately following handover and also during the second shift were taken as measures of shift handover effectiveness. Shift handover using the structured, checklist-integrated logbook was compared to handovers that used the legacy, less structured ENGEN Refinery logbook. Although the differences between the two handover approaches were not large, the effect on logbook quality was statistically significant and there were trends toward significant different in the other two measures of effectiveness. Based on these findings, we conclude that providing a sound structure for logging and shift handover, based on key categories of situational information, will likely improve the effectiveness of shift handovers.

While we can only speculate about why larger differences between the two approaches were not observed, it is likely a result of the rather experienced pool of operators who participated in the study. These operators had a median of 20.35 years of operations experience. Even the least experienced operator had spent 6 years in operations. Likewise, these operators were rather experienced in operating a Distributed Control System (DCS), with a median of 6.5 years of DCS experience, which ranged from 1 to 25 years. One would expect that, with all this experience, these operators would have a pretty good idea about what events and information are important to communicate to the second shift, even with little structure imposed on them. We would expect them to perform relatively well in both conditions. Therefore, we can speculate that the increase in effectiveness observed here, though relatively small, is likely a conservative estimate of the benefit of structuring the shift handover around a checklist logbook. Were we to repeat the experiment with less experienced operators, we might expect to find larger differences in performance. Future research needs to address that hypothesis. This question is particularly important in view of the trend in North American refineries toward less experienced personnel in the control room due to retirements in the experienced segment of the workforce. Thus the potential of checklist-structured logging and shift handover to compensate for lack of experience needs to be explored.

One might expect that using the checklist logbook would increase the amount of time required to conduct shift handovers. In the current experiment, shift handovers using the checklist logbook took marginally longer on average than the less structured handovers. However, the time was roughly within the “5-10” minutes often cited as the desired amount of time for shift handover. As one of the participants pointed out in the post-experiment debriefing, filling out the checklist logbook is the most time-consuming aspect of using it. However, it is mostly filled out during the shift and so does not place any significant burden of time on the handover briefing itself. The marginally longer times for structured shift handovers also can be viewed in cost-benefit terms. The small additional amount of time required is more than compensated by the increase in quality of the communicated information. Finally it would be valuable to validate this conclusion by recording the duration of shift handovers in actual operations at a refinery such as ENGEN that has introduced the checklist-integrated logbook into its operations.

Improving communication skills may also be a way to improve shift handovers of both experienced and inexperienced operators. A more controlled investigation of necessary training for communication skill was beyond the scope and resources of this project. However the post-hoc analysis of shift handover verbal interactions revealed that while some effective communication practices were commonly practiced by operators during shift handover, some other practices were not. The latter may provide opportunities to improve shift handover communication through training that focuses on these specific communications skills and practices. Future research should more systematically investigate the extent to which these skills can be trained, what that training should consist of, and what effect training has on shift handover effectiveness. That research also needs to address what is required to maintain over time the new communication skills learned during the initial training.

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