Measuring the Influence of Human Factors on Operational Performance in Resource Industry Workplaces

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1. Introduction

Although much research has hypothesised the ability of human factors to influence outcomes in the workplace, more research is required to demonstrate statistically valid associations between the operation of specific human and organisational factors, and technical measures of performance, such as reliability.

Plant reliability (Dhillon, 2002) is an important consideration for any organisation that depends on predictable and safe operation of facilities and equipment. This is particularly the case where the risks are high, as in hazardous environments such as petroleum production (Øien, 2001). Although non-technical factors, e.g. communication, decision-making and situation awareness, have been recognised as contributing to operating reliability (O'Connor & Flin (2003), according to Reiman & Oedewald (2004) objective measures for quantifying the relationship are still needed.

Dekker (2010) discusses the complicated nature of failures in complex systems, particularly in the way that various factors interact. To analyse the contributors to these failures, various methodologies have been developed based on relevant frameworks. For example, Rasmussen’s (1982) Model of Human Malfunction underpins various investigation and analysis tools that have been developed to determine the role of human factors as contributors to failures and accidents. One of these tools was the Human Factors Investigation Tool (HFIT) developed by Gordon (2001), which was specifically developed for the North Sea petroleum industry. In a previous study of the human factors contributing to failures in petroleum operations, Antonovsky, Pollock, & Straker (2014) demonstrated, through structured interviews based on the HFIT tool, that the most frequent contributors to failures in that domain were: 1) Assumptions, 2) Design & Maintenance, and 3) Communication.

The objective of the current research was to measure the perceptions of personnel in petroleum operations concerning the human factors that had previously been identified as frequent contributors to failures. These measures were then used to determine if there was a statistically valid relationship with technical measures of reliability in their work area.

2. Method

2.1 Design and Measures

This study utilised a 3x3 independent group design with Reliability (higher, middle, and lower) and Facility Type (FPSO, Gas Platform, and Process Plant) as independent variables (IVs). The Mean Time Between Failures is an accepted measure of reliability (International Standards Organization,
In this study, the number of plant stoppages within a given period was the basis for assigning a relative reliability level.

Validated measures for constructs relating to the most frequent contributors to failures identified in the previous study (Antonovsky et. al, 2010) were sought from the literature to provide the dependent variables (DVs). Problem-solving and Vigilance were a proxy for Assumptions, as a validated instrument for assumptions was not found. The Problem-solving scale in the Work Design Questionnaire (Morgeson & Humphrey, 2006) was used to measure workplace requirements for problem-solving. Vigilance in decision-making was measured using the Vigilance scale in the Melbourne Decision-Making Questionnaire. (Mann, Burnett, Radford & Ford, 1997)

Scale items for Design & Maintenance were constructed from the items in HFIT, which was validated by Gordon, Flin & Mearns (2005). The OCD/2 questionnaire developed by Wiio (1978) was used to measure the quality of work-related communication. A multiple choice questionnaire comprised of these scales was used as the measurement instrument for the DVs.

2.2 Participants

Participants (N=428) were recruited from:

- Three Floating Production, Storage and Offloading (FPSO) facilities;
- Three off-shore gas platforms.
- Three maintenance areas in the Gas Process Plant;

A response rate of 41.6% (n=178) was obtained.

3. Results

The Design & Maintenance and Communication items were subjected to separate Exploratory Factor Analyses (EFA) to identify an underlying factor structure. The EFA suggested a two-factor solution for Communication, which were termed Job-related feedback and Information about change. The EFA for Design & Maintenance suggested a single factor for the scale items.

Between-group analyses were conducted to determine if significant differences in questionnaire responses existed between work area reliability levels. The analyses consisted of a series of 3 x 3 (two-way) analyses of variance (ANOVA) with the independent variables based on a three-level ranking of reliability (lowest, middle, and highest) across three different facility types (FPSO, Gas Platform, and the Process Plant) using the dependent variables (DVs) derived from the survey measures.

The main effect of Reliability Level on Problem-solving was found to be significant. Respondents from the lower reliability facilities expressed more agreement with items referring to a need for Problem-solving than those from higher reliability facilities (Figure 1).
The two-way ANOVA showed no significant effect of Reliability Level on Vigilance. Reliability Level for FPSOs was found to have a significant effect on perceptions of Design & Maintenance. Reliability Level accounted for 21.5% of the variance, a large effect size (Figure 2).

The ANOVA showed no significant main effect of Reliability Level on perceptions of Information about change, or Job-related feedback, the two measures of communication. However, the results did indicate a significant correlation ($r=0.371, p=0.01$) between Job-related feedback and Employer (company employee vs. contractor employee), suggesting an organisational-level difference.
4. Discussion

The results demonstrated that significant group-level differences in perceptions existed in the variables Problem-solving and Design & Maintenance based on reliability level, but not the other variables and not for all facility types. Higher reliability was associated with responses indicating perceptions of better maintainability and plant design. Lower reliability was associated with a greater perceived requirement for problem-solving behaviours.

It was also found that perceptions of Vigilance and Communication were not differentiated by differences in group-level reliability. One implication is that behaviours involving decision-making and communication were contributing factors to maintenance-related failures, but were not perceived as important factors in day-to-day operational reliability. An alternative explanation is that the measures selected for testing Communication were sensitive to organisation-level phenomena. This was demonstrated by the significant differences in response obtained between company employees and contractors. The latter explanation is supported by the research of Zohar & Luria (2005) who identified that some phenomena emerge at the group-level, while other phenomena are apparent at the organisational level.

Overall, the results demonstrated that by utilising appropriate measurement instruments, the perceptions of personnel concerning human factors in their workplace could be statistically related to technical measurements of plant reliability. Furthermore, given an appropriate conceptual framework, these measures of human factors could be based on the factors that are found to frequently contribute to failures in complex systems. However, care must be taken to ensure that the correct level of analysis is investigated i.e., group level or organisational level. These findings have important implications for the prediction of plant performance based on both the history of past failures and the knowledge of the workforce.

References


