OGP

Crew Resource Management for Well Operations teams

Report No. 501
April 2014

International Association of Oil & Gas Producers

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Revision history

Version	Date	Amendments
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Acknowledgements

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The Industrial Psychology Research Centre at the University of Aberdeen wishes to gratefully acknowledge the co-operation and assistance provided by the steering group members and the operating, drilling and service company managers who granted access and facilitated arrangements for the interview study. We would also like to take this opportunity to thank the wells personnel who participated in the interviews for this study.

Foreword

Introduction

The importance of non-technical skills to safety and efficiency has long been recognised in high risk industries such as aviation, mining, rail and healthcare. To date, the oil and gas exploration and production industry has not paid the same attention to providing training in cognitive, human factor skills such as situation awareness and decision making. Until recent events, such as the blow outs experienced on the Macondo and Montara wells, the oil and gas industry had not fully recognised the importance of how psychological factors relating to perception and motivation can contribute to safe and efficient operations. It is now believed that a step-change improvement in operational safety and efficiency of well operations teams (*i.e.,* the full spectrum of drilling, completions, work-overs & interventions), can be achieved through effective development and application of *non-technical skills*, also known as Crew Resource Management (CRM).

The International Association of Oil and Gas Producers (OGP) initiated a research project with University of Aberdeen Industrial Psychology Research Centre to develop recommended content for a syllabus for CRM (non-technical skills) training in well control; customised to the needs of well operations team-members. This work was jointly managed by the Wells Expert Committee (WEC) and the Safety Committee's Human Factors Subcommittee. The syllabus that is the result of this work is published in this report. The intent of this training is to supplement OGP report No 476, *Recommendations for enhancements to well control training, examination and certification* (http://www.ogp.org.uk/pubs/476.pdf).

Vision

Looking forward, specifically in the area of well operations, the oil and gas exploration and production industry must recognise the importance of non-technical skills to operational safety, and embed discipline-relevant skills and attitudes in training and operational practices. Training alone will not bring a step change in our industry; however, a period of stand-alone CRM training is imperative to build an appreciation for the importance of human factors and to establish a foundation of knowledge and ability.

The suggested course syllabus focuses on improving the skills of the individual worker in a team setting and addressing behaviour in routine operations, with the aim of avoiding critical incidents. However, the skills taught in this course can also be applied when dealing with time pressured critical events. The course syllabus is based on current scientific research into human performance. The course content developed from the recommended syllabus should be adapted to the operational conditions and task demands, as well as to the needs and existing knowledge of the trainees.

Beyond the period of stand-alone training, CRM concepts should be incorporated into technical training courses. Such integration will help develop and sustain the awareness, knowledge and (instinctive) application of non-technical skills. Operationally, CRM concepts must be known, and their importance recognised, by leadership teams at all levels as well as incorporated into safety debriefs, operational procedures and operational audits.

On-going plan of work

In order to develop and deliver the required CRM course, training providers will require information additional to the suggested Well Operations Crew Resource Management (WOCRM) syllabus. Therefore, there is on-going work to build on this content and generate a recommended practice for Crew Resource Management for well operations teams (OGP report No 502).

This new recommended practice will define the requirements for CRM applied to well operations teams performing drilling, completions & interventions of all types of wells, worldwide. The recommended practice could be used by training providers to develop courses that are consistent and quality assured.

The developers of this on-going work will engage with several key parties in the industry that have already led the way by developing their Crew Resource Management training material.

Definitions

For the purposes of this document, the following definitions apply:

Crew Resource Management or **non-technical skills** (also called CRM, NTS, or human factor skills) is a term that came from the aviation industry and can be defined as '*the cognitive, social and personal resource skills that complement technical skills, and contribute to safe and efficient task performance*' (Flin et al, 2008).

Well operations team-members: engineers and technicians who perform operational roles in drilling, completion, work-over & intervention operations defined as requiring certification in well control.

OGP recommendations

Following review and discussion of the report by the University of Aberdeen, OGP has developed recommendations for the implementation of a CRM training course, which will form the basis of the OGP's Recommended Practice (refer OGP report No 502).

OGP *Well Operations Crew Resource Management* (WOCRM) training syllabus project

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Executive summary

The project was commissioned by OGP's Safety Committee (via the Human Factors Sub-Committee) (HFSC) and the Wells Expert Committee (WEC) (via the Human Factors—Training, Competency and Behaviours Task Force).

The aim was to develop a recommended syllabus for Crew Resource Management (CRM) training customised to the needs of Well operations teams (i.e. performing Drilling, Completion, Intervention & Work-over operations).

In order to identify the basic categories of CRM (non-technical skills) skills that are required by wells operations personnel, 17 key roles were identified. The literature on human factors in wells operations was reviewed, as well as relevant material on CRM training and assessment in offshore production operations and in other industries. In addition, a sample of 33 wells personnel was interviewed and asked about the non-technical skills required in routine and non-routine work conditions.

Evidence from these two sources was used to develop an outline for a basic syllabus for Well Operations Crew Resource Management (WOCRM) training. This consists of an introductory module, plus coverage of the main non-technical skill categories: *Situation Awareness, Decision Making, Communication, Teamwork, Leadership*, and *Performance shaping factors—stress and fatigue*.

Recommendations for the design and delivery of basic and recurrent WOCRM training are provided.

Contents

1. Introduction

1.1 Background

This project was sponsored by a joint initiative between OGP's Safety Committee (via the Human Factors Sub-Committee) (HFSC) and the Wells Expert Committee (WEC) (via the Human Factors —Training, Competency and Behaviours Task Force). The aim of the project was to develop a recommended syllabus for Crew Resource Management training customised to the needs of well operations teams (*i.e.,* drilling, completion, intervention & work-over operations). The Well Operations Crew Resource management (WOCRM) syllabus has been designed to meet one of the key recommendations being made by the HFSC based on its study of process safety and environmental incidents in drilling (OGP, 2012a), as well as being a significant contribution to the work of the Wells Expert Committee Task Force on Human Factors.

1.2 Well operations

The oil and gas exploration and production industry is a worldwide operation, with both onshore and offshore facilities, designed to meet global needs for the location and supply of energy. In the twenty-first century, these operations have been characterised by increasing complexity, particularly the deep water environments and the high temperature, high pressure wells (Glass, 2005). The drilling industry has recently experienced a number of accidents that have caused significant concern, most notably the blowout on the Montara well in Australia (Borthwick, 2010) and the blowout on the Deepwater Horizon rig on the Macondo well in the Gulf of Mexico (National Commission, 2011). These events have resulted in a widespread industry response and various task groups were established which have produced reports and guidelines on key aspects of these accidents.

1.2.1 Competencies

One particular area of interest has been on the competencies of wells personnel; for example the Oil Spill Prevention and Response Advisory Group (OSPRAG, 2010; 2011) had a specific task group to examine competency, behaviours and human factors. They recommended that "leadership and supervisory competencies should be established and assessed"(p. 12) for a number of occupational roles for wells operations and this was taken into account in the *Guidelines on the Competency of Wells Personnel* issued in January 2012 (Oil & Gas UK, 2012). These state that "competency systems should address critical competencies commensurate with operational risk, consequence and well complexity" (p. 9) and suggests that "*a useful system covering non-technical ("non-tech") aspects of competency is crew resource management (CRM). This is used to improve team competency and understanding by some drilling contractors, as well as industries including aviation and marine*". (p. 16).

Similarly, the Norwegian Oil and Gas (formerly OLF) report *Deepwater Horizon—Lessons Learned and Follow Up* (OLF, 2012), recommended that "the industry gives consideration to introducing CRM or similar scenario-based team behaviour training for well-site and support personnel" (Recommendation 29, p. 30).

1.3 Crew resource management and non-technical skills

The concept of Crew Resource Management (CRM) was originated by NASA in the late 1970s to help flight crews improve their skills in areas such as teamwork, leadership, situation awareness and decision making (CAA, 2006; Kanki *et al*, 2010). The concept has since been successfully translated to a wide range of other higher-hazard industries, such as the fire services, marine, rail, mining and healthcare.

The related term non-technical skills (also called CRM skills) came from the European aviation industry. They can be defined as "*the cognitive, social and personal resource skills that complement technical skills, and contribute to safe and efficient task*

performance" (Flin *et al*, 2008, p. 1). These are not new or unfamiliar to most workers: they are essentially what the best practitioners do in order to achieve consistently high performance. The importance of non-technical skills to safety and efficiency has long been recognised in higher-risk work settings.

Adverse outcomes in well operations have been associated with failures in these non-technical aspects of performance—team working, risk assessment, leadership, decision making, and communication (Wilson & Stanton, 2001; OGP, 2012b). Wells personnel working for operating, drilling and service companies may receive training in leadership, teamwork and communication skills as part of personal development, supervisory or safety training. They may also have received guidance in the management of stress and fatigue from occupational health programmes. There appears to have been less attention devoted in this sector to training the cognitive, non-technical skills of situation awareness and decision making, although the importance of psychological factors relating to perception and motivation was noted by well control specialists twenty years ago (*e.g.* Sonneman, 1992).

What is distinctive about CRM programmes, compared to the types of training mentioned above, is that they cover all these non-technical skills in one course and that the teaching material is evidence based. Other notable features of CRM training are:

a. Based on an ongoing analysis from company or industry sources (*e.g.* reporting systems or accident data) of the social, cognitive and personal resource (non-technical) skills required for safe and efficient operations;
b. Focused on the individual worker in a team setting—the assumption is that workers need 'portable team skills' for whatever team or crew they find themselves in on a given shift;
c. Not about personality but about behaviour;
d. Addresses behaviour in routine operations with the aim of avoiding critical incidents, as well as skills for dealing with a critical event
e. Founded on current scientific research into human performance in that work setting.

In the aviation, nuclear and marine industries, operational staff regularly receive CRM training to maintain or improve their non-technical skills. In the UK, it is mandated that civilian pilots must not only receive regular CRM training but they must also have their CRM skills formally assessed as part of their regular licence revalidation (CAA, 2006). There has been very limited application of this type of comprehensive CRM training in the upstream oil and gas industry, with the exception of some developments post Piper Alpha (Flin, 1995; Flin *et al*, 2002a,b; O'Connor & Flin, 2003), some of which were focused on emergency response (Grinde, 1994). There are some recent initiatives to introduce CRM type training for wells personnel (see below) but there are no oil and gas industry standards for non-technical skills competency frameworks, nor an approved CRM training syllabus for wells personnel. It is anticipated that the introduction of WOCRM training will result in benefits not only for safety performance but also for operational performance.

I.4 Purpose and rationale

The purpose of this project was to begin to identify the key categories of non-technical skills required by wells personnel, in order to develop a generic training syllabus covering a range of non-technical skills considered to be particularly important to improving safety and efficiency in well operations. The output presented below is a recommended syllabus for Well Operations Crew Resource Management (WOCRM) training and assessment.

The focus of the project was limited to engineers and technicians who are required to meet industry standards for certification in Well Control

(Oil & Gas UK, 2012). The project scope did not cover: i) specification of training and competence requirements for CRM Instructors; ii) development of recommendations for specifying or mandating demonstrations of competence in CRM skills that may be expected of drilling crew.

A set of 17 wells roles (in three main categories: machine operator; supervisors; and support) of principal interest were established by the steering group for this project (see Table 1 adapted from OSPRAG (2010) Guidelines, positions for competence assessment).

Table 1. Categories and roles for CRM training syllabus

MACHINE OPERATOR:	SUPERVISORS:	SUPPORT:
Driller/operator	**Toolpusher**	**Roughneck**
Assistant driller/operator	**Rig manager (office)**	**Derrickman**
	Company man	**Mud logger**
	Drilling supervisor	Drilling fluids engineer
	Superintendent (office)	Cementer
	Well services supervisor	
	Well test supervisor	*Directional driller*
	Coil tubing supervisor	*MWD/LWD engineer*
	Slickline supervisor	*Subsea engineer*
	Completions supervisor	*BOP/LMRP engineer*
		Well integrity supervisor
	E-line supervisor	*Production supervisor*
	OIM	*Petroleum engineer*
	Senior drilling engineer	*Operations geologist*
	Drilling engineer	*Development geologist*
	Senior completions engineer	*Reservoir engineer*
	Completions engineer	*Sub surface lead/manager*
	Well Engineering manager	

NOTES:

1. 'Operator' applies to completions, work-overs & interventions and is the person directly operating the work unit.
2. Roughneck, directional driller and MWD/LWD engineer are the only roles added to the OSPRAG/Oil & Gas UK list.
3. **Bold** indicates top priority for each category.
4. Roles in *italics* are not required for CRM analysis at this stage; therefore no interviews were conducted as part of University of Aberdeen's work
5. Role names can vary across the industry and between different companies.

2. Method

Within the time scale of the project, two methods of data collection based on task analysis techniques (Flin *et al*, 2008) were feasible for providing a preliminary identification of the main categories of non-technical skills required by wells personnel. The first of these was to search the existing scientific and industry literature for studies of non-technical skills in drilling/well operations and to look for studies that had designed and evaluated CRM training for this work group. The second method was to conduct an interview study with key members of the 17 wells operations occupations listed above in order to identify the non-technical skills they referred to when discussing their work.

These methods have been applied before in previous investigations that identified non-technical skills, for example, for scrub nurses (Mitchell *et al*, 2011) and surgeons (Yule *et al*, 2006).

2.1 Literature search

Papers and reports were read and specific examples of behaviours relating to the non-technical skills categories of situation awareness, decision making, communication, leadership, team work, effects of stress and fatigue were identified.

2.2 Interviews

2.2.1 Interview schedule

Drawing from the literature search, as well as our previous research into human factors in offshore operations (Flin & Slaven, 1996), a prototype CRM course for offshore crews (Flin *et al*, 2002a; 2002b), CRM skills in drill crews (*e.g.* Sneddon *et al*, 2006), and previous interview studies of non-technical skills for medical professionals (*e.g.* Mitchell *et al*, 2011), an interview schedule was devised for use with experienced wells personnel (see Appendix 1). This used a critical incident method (Flanagan, 1954, Crandall *et al*, 2006), as well as specific questions (13 in total), to ask interviewees about their work in order to extract information on key non-technical skills for safe and efficient operations.

2.2.2 Sample

With the assistance of the project team and personal contacts, companies employing personnel in the list of 17 wells roles in Table 1 were contacted and asked if they would invite their staff to volunteer for interviews. A sample of 33 wells professionals (two female) were interviewed, mostly by telephone. They worked mainly in offshore roles, for three operating companies, four drilling companies and three service companies. Some of the more senior positions had experience of other roles, *e.g.* toolpushers and rig managers who had previously been drillers.

The list of roles interviewed is as follows: Driller (1); Assistant Driller (1), Toolpusher (2) Roughneck/ Roustabout (3); Floorhand (1); Derrickman (1); Mud Logger (2); Mud Engineer (1); Cementer (2); Well Test Supervisor (2); Coil Tubing Supervisor (2); Completion Supervisor (2); Slickline Field Manager (1); Wireline Supervisor (1); Rig Manager (onshore office—drilling contractor) (2); Drilling Supervisor/Drilling Engineer/'Company Man' (8); Superintendent (onshore office—operating company) (1). It should be noted that some of the job titles are different from the roles listed in Table 1, as these vary across companies.

2.2.3 Procedure

With the interviewee's permission, the interview was audio recorded, transcribed and then analysed. Using the software package NVivo 9, a structured coding method was employed to identify examples of behaviours mentioned by the interviewee related to the main categories of non-technical skills. The coding frame (Appendix 2) was adapted from an earlier study of CRM skills for oil and gas industry offshore installation personnel (Flin *et al*, 2002a; 2002b).

3. Results— Identifying the key non-technical skill categories

3.1 Literature review results

From the literature search, there appeared to be no published studies of CRM training specifically for wells personnel/drilling crew, although there were some with platform crews. There have been psychological or human factors studies on offshore crews dating from the 1990s, mainly from Norway (*e.g.* Hellesoy, 1985) or the UK Sectors (*e.g.* Flin & Slaven, 1996) but more recently from other countries such as China (Chen *et al*, 2008) and Brazil (Menezes, 2004). These investigations either include wells personnel in the samples or the findings from offshore platform crews are applicable to them. The investigations tend to be on occupational health, related mainly to stress and fatigue associated with the offshore work environment (Sutherland & Cooper, 1991; Parkes, 1998).

There are UK (Wilson & Stanton, 2001) and Norwegian reports (PSA, 2005) on human factors in drilling and wells operations and on the driller's work situation (PSA, 2007) which emphasise the complexity and time pressure of the job and required communication and leadership skills. Sonneman (1992) discussed the psychology of well control, focussing on factors influencing the driller's decision making. In terms of non-technical skills, the recent Oil & Gas UK (2012) guidance for wells personnel identifies leadership, supervision, risk assessment and team management as required competencies. The recent report on cognitive issues associated with process safety incidents (Report No460, OGP, 2012b) highlighted the importance of situation awareness, decision making, interpersonal behaviours (teamwork, communication). Situation awareness, stress and fatigue in drill crew members have been examined (Sneddon *et al*, 2006; 2013), as well as shared understanding in drilling operations (Haavik, 2011).

The National Commission Report (2011) on the Deepwater Horizon accident identifies in chapter 4 deficiencies in risk assessment and decision making. Hopkins' (2012) analysis of the event also underlines the failures in situation awareness, decision making and leadership in both offshore and onshore personnel. The Inquiry into the Montara blowout (Borthwick, 2010) describes it as "a failure of 'sensible oilfield practice 101'" (p. 11) and goes on to discuss similar problems. Hayes (2012), examining this accident, discusses 'significant flaws in decision making' (p. 569) and problems in supervision.

3.1.1. Key NTS categories from the literature

All these literature sources were scrutinised to extract key categories of non-technical skills for wells operations. This suggests that for a generic syllabus on CRM/non-technical skills for wells personnel, the following skill categories are likely to be required:

- Situation Awareness
- Decision Making
- Communication
- Leadership/Supervision
- Teamwork
- Awareness of performance shaping factors *e.g.* stress and fatigue

In many cases, the behaviours being discussed relate to communication although it is not always listed as a separate skill category for CRM rating tools (*e.g.* NOTECHS), given its ubiquitous role as an observable behaviour when rating other skills such as teamwork (see Flin *et al,* 2003 for further discussion.) However it was decided that due to the importance of communication skills in wells operations, this should be set as a separate category. Thus from the literature review, the same categories of CRM trained in other industries appear to be relevant for wells personnel and should be included in the WOCRM syllabus.

It is understood that a number of drilling companies (*e.g.* Maersk) and operating companies (*e.g.* BP, Statoil) have recently introduced some type of human factors or Crew Resource Management training and/or are providing feedback on non-technical skills for drilling

and wells crews undergoing simulator-based training. There are also industry bodies (*e.g.* IWCF, NOGEPA) supporting the inclusion of non-technical skills components in technical, scenario-based well control training. However, little published information was available from these initiatives, when the literature search was conducted.

3.2 Interviews—Results

The objective in this study was not to undertake a full task analysis for each of the 17 roles but to determine the main categories of non-technical skills for a training syllabus for wells personnel in general. So the analysis below is not divided by role. In previous studies to design full non-technical skills frameworks and assessment systems (*e.g.* Fletcher *et al*, 2004; Yule *et al*, 2006), much larger numbers of role occupants (*e.g.* 25 per role) have been interviewed *for each position*. The 33 interviews covered key roles for wells operations. As mentioned above, more senior personnel had typically worked in more junior positions and sometimes referred to these offshore roles.

The transcribed interviews were coded to extract examples of behaviours relating to non-technical skills relevant to wells operations. Whenever an interviewee made reference to a particular behaviour related to a non-technical skill, such as talking about how a crew worked together during a challenging operation or decisions made during a typical shift, these extracted text segments (in total 1224 segments) were allocated a code (see Table 2). The codes related to six categories of non-technical skills that had been identified from the literature and within these, were 27 corresponding elements (derived from previous offshore CRM research). For example, the Teamwork element 'considering others' was mentioned 94 times across all the data; interviewees frequently described how they 'looked out for' other team members and how they considered other people in the crew.

Table 2: Frequency of identified CRM element from 1224 codes

CODING LABELS	FREQUENCY
Considering others (TW)	94
Awareness of surroundings (SA)	91
Supporting others (TW)	76
Conflict solving (TW)	66
Shared mental models (SA)	66
Plant status awareness (SA)	64
Maintaining team focus (TW)	56
Identifying and managing stress (PR)	54
Assertiveness or speaking up (C)	50
Asking questions (C)	50
Listening (C)	50
Maintaining standards (SL)	48
Team decision making (TW)	48
Planning and co-ordination (SL)	44
Anticipation (SA)	43
Option generation or choice (DM)	40
Risk and time assessment (DM)	40
Attending to non-verbal signals (C)	37
Use of authority/assertiveness (SL)	36
Reducing or coping with fatigue (PR)	35
Giving appropriate feedback (C)	29
Concentration or avoiding distraction (SA)	27
Problem definition or diagnosis (DM)	25
Workload management (SL)	20
Physical and mental fitness (PR)	16
Recognition primed decision making (DM)	10
Outcome review (DM)	9

NOTE:

(SA) Situation Awareness; (TW) Team Working;
(C) Communication; (PR) Personal Resources;
(SL) Supervision and Leadership; (DM) Decision Making

These codes were used to build a profile of the generic non-technical skills being used in wells operations and to show what common behaviours are emerging. The data (see Table 2, and Figure 1) feature two dominant categories: Teamwork and Situation Awareness, which were found across all roles. Communication and behaviours relating to dealing with Personal Resources (stress and fatigue) were also found in the transcripts. Other categories, such as behaviours relating to Leadership and Decision making, were typically mentioned in relation to more senior roles for wells operations. Examples from the transcripts are given in Table 3. It should be emphasised that these are preliminary data from a small sample and the frequency with which behaviours are mentioned may relate to the specific situations discussed and question set used and therefore these figures should only be taken as indicative of their relevance for wells operations.

Figure 1 shows the percentage of the data (extracted units of behaviour) related to each category.

Figure 1: Percentage of data related to NTS categories

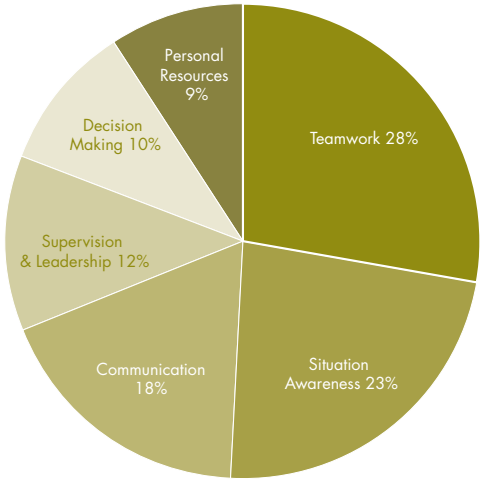

Table 3: Examples of behaviours allocated to CRM (NTS) categories

NON-TECHNICAL SKILLS CATEGORIES	EXAMPLES FROM THE INTERVIEWS
Situation Awareness	Observing the monitors, pressures and weights and reporting any concerns immediately. Looking around for hazards on the drill floor e.g. trip hazards, equipment left in unsafe conditions. Walking around. Checking equipment. Keeping an eye out for items coming down from the derrick. Making sure items don't get caught when moving. Observations of the drill floor at regular intervals.
Decision Making	Assessing progress and reporting issues and problems. Coming 'off the Well' in adverse weather. Working together as a team to provide an adequate solution or outcome. Stopping the operation if safety is compromised.
Communication	Attending all meetings and toolbox talks. Carrying out a management of change if necessary. Speaking up at meetings and voicing any concerns or asking questions. Listening.
Team Working	Looking out for others on a personal and on a professional level. Attending pre-job meetings Looking out for people standing in harm's way. Guiding people on where to stand safely. Liaising with different members of the crew at regular intervals. Diplomacy. Listening to others and making assessments and decisions as a group.
Personal Resources	Looking out for members of the crew that may have personal issues. Identifying if personal issues are impacting upon the job or other crew members. Seeking assistance with heavy equipment.
Supervision & Leadership	Being direct and clear about the jobs that need done. Planning each job and making sure all personnel are aware of their role. All permits/TRIC cards in place prior to operation. Using authority where appropriate. Watching for any change in crew's demeanour.

As stated previously, it should be noted that this analysis from the set of interviews is not meant to provide a fully comprehensive or in-depth analysis of the non-technical skills required for wells operations. Moreover the behaviours that workers choose to discuss when being interviewed may not entirely correspond to the non-technical skills set required.

Nevertheless, when taken in combination with the literature review, which drew evidence from a wider range of sources, there appears to be sufficient justification for the inclusion of the following categories of non-technical skills in a Wells Operations CRM course.

3.3 Identified non-technical (CRM) skill categories

The main categories identified from the literature review and the interviews in relation to the three groups of wells operations roles are shown in Table 4.

It may be of benefit for personnel who do not have a specific responsibility (*i.e.* leadership, decision making) to engage in the discussion of that skill category. In the case of leadership, this is for two reasons: a) leadership training should encompass a discussion of followership expectations and behaviours, and b) some crew members will be promoted to supervisory positions requiring leadership skills later in their careers. In the case of decision making, all personnel make task-related decisions (and have the right to ask for operations to be stopped on safety grounds), but it is normally only those in positions of higher responsibility (*e.g.* driller, company man) who make the on-site decisions of higher significance and consequence. These types of decisions might involve changes from accepted practices, or deviations from agreed work plans, in response to a particular situation.

Therefore, it is proposed that for the initial stage of this industry initiative that a single generic syllabus for CRM training is developed for wells personnel. Many of them will have limited familiarity with the underlying concepts and so it is suggested that most personnel will require an introduction to the six basic CRM categories and their application for wells operations.

Table 4: Proposed skill categories by wells role group from interview data

	DRILLERS	SUPERVISORS	SUPPORT
CRM SKILLS			
Situation Awareness	✓	✓	✓
Decision Making	✓	✓	?
Communication	✓	✓	✓
Teamwork	✓	✓	✓
Leadership	✓	✓	n/a
Stress & Fatigue	✓	✓	✓
NOTES			

1. Drillers = Machinery operator (Driller, Assistant driller).
2. Support (this is more complex, as drilling fluids/mud engineer (may also include cementer if service hand is responsible for cement decisions) may need to have decision making, but may be less responsibility for major decisions for roughneck, derrickman and roustabout).

4. Descriptions of the key non-technical skill categories

In this section, each of the six main categories of non-technical skills to be included in the WOCRM syllabus is shown with component elements. These have been derived from our previous CRM research for offshore crews, the wells operations literature outlined above and the interview data. In Table 3 some examples of specific behaviours are given. The focus is on non-technical skills and their related behaviours while the individual is engaged in a technical task. It should be noted that these are individual skills, and therefore portable. That is, the person should be able to use these skills in any wells team.

An overview of the main non-technical skills categories and the suggested skill elements to be covered in training is provided in Table 5. It should be noted that this is not a validated taxonomy, nor is it designed for any particular role. It is a proposed set of CRM skill components that could be covered in a generic WOCRM training course.

Table 5: Proposed WOCRM skills components for a generic syllabus

CATEGORY	ELEMENTS
Situation Awareness	• Gathering information • Understanding information and risk status • Anticipating future state/developments
Decision Making	• Identifying and assessing options • Selecting an option and communicating it • Implementing and reviewing decisions
Communication	• Briefing and giving feedback • Listening • Asking questions • Being assertive
Team Work	• Understanding own role with the team • Coordinating tasks with team members/other shift • Considering and helping others • Resolving conflicts
Leadership	• Planning and directing • Maintaining standards • Supporting team members
Performance shaping factors—stress and fatigue	• Identifying signs of stress and fatigue • Coping with effects of stress and fatigue

5. WOCRM syllabus

Based on our previous work designing CRM courses for offshore control room operators and platform crews (Flin *et al*, 2002a; 200b), and the findings outlined above on wells personnel, a sample syllabus for a two day course covering the core non-technical skills topics is outlined below. This should be adapted to the operational conditions and task demands, as well as to the needs and existing knowledge of the trainees. The focus should be mainly on routine conditions where the non-technical skills are protective for safety. The same skills will also be required in time pressured, emergency events, although typically at a higher level.

As with other types of training, it would be beneficial when the CRM training is being introduced, for the course to be opened with a short introduction from a Wells Manager or equivalent to indicate that the course had the support of management and to outline the reasons why this type of training is deemed important to the organisation.

5.1. Suggested content for a WOCRM syllabus

DAY ONE

Introduction

The aim of this module is to provide the participants with a basic understanding of human factors in relation to workplace safety, the origins of CRM as a human factors/error management approach, and the relevance of CRM (non-technical) skills to safe and efficient wells operations.

- Explanation of human factors and importance in safety critical work settings.
- The common nature of human error. Influence of system factors (*e.g.* Reason's [1997] Swiss cheese model) and environmental threats—(*e.g.* Helmreich's [2003] threat and error model), as well as of human error, in accidents.
- Brief history of CRM, and its roots in the aviation industry as an error management approach. Examples of failures in CRM/non-technical skills that have been shown to contribute to accidents or where good non-technical skills have contributed to avoidance of/recovery from adverse events.
- The rationale for CRM training for wells personnel (*e.g.* Macondo; Montara; local wells events, OGP wells competencies).
- Aims of WOCRM course and topics to follow

Skill 1: Situation Awareness

The aim of this module is to give the participants an understanding of the concept of situation awareness, component skills and influencing factors. Typical situations relating to wells operations (*e.g.* OGP wells incidents database) could be presented for trainees to practise identifying cues, forming an understanding and anticipating how the situation could develop.

- Definition of situation awareness (e.g. *'Developing and maintaining a dynamic awareness of the situation and the risks present during a wells operation, based on gathering information from multiple sources from the task environment, understanding what the information means and using it to think ahead about what may happen next*).
- Its application to wells personnel (*e.g.* well control events showing SA problems).
- Component skills: gathering information, comprehension of situation and risk status (forming a mental model) and anticipation (projection). Situation awareness three stage model (*e.g.* Endsley, 2000). Dynamic risk assessment (*e.g.* Tissington, 2005)
- The causes and symptoms of situation awareness problems (*e.g.* inattention, distraction)
- Recognising and combating situation awareness problems

Skill 2: Decision Making

This module examines individual decision making. It can describe different ways of decision making, and outline the well control situations to which each type is applicable and factors which have a detrimental effect on decision making. Decision making exercises based on wells scenarios can be used for practice and discussion. It should be acknowledged that some wells roles have more significant decision making responsibilities than others.

- Definition of decision making (e.g. *Skills for diagnosing the situation and reaching a judgement in order to choose an appropriate course of action*).
- Problems in wells operations with decision errors (*e.g.* confirmation bias, fixation).
- Component skills (assessing the situation (problem, time, risk) then choosing a course of action, and reviewing the outcome.
- Different modes of on-task decision making (*e.g.* slower analytical, comparing options *vs* procedure based *vs* faster, gut feel, intuitive, pattern matching method) and suitability for different situations.
- The human memory system and how it influences decision making.
- Workplace factors affecting decision making.

Skill 3: Communication

The topic of this module focuses on the critical role of communication for safe and efficient wells operations and the factors that influence it. Particular emphasis should be given to feedback, listening, briefing and assertiveness. Communication skills relevant for wells operations could be practised with feedback provided. This module should cover communication issues both on an installation, and between site and off-site personnel.

- Definition of communication (e.g. *Skills for the exchange (transmission and reception) of information, ideas and feelings, by verbal (spoken, written) or non-verbal methods*).
- Requirements of good communication: examples of problems in well operations relating to communication problems in the crew, with the 'beach' and with the other shift
- The advantages and disadvantages of one and two way communication; the importance of feedback; Briefing and debriefing; handovers
- Internal and external barriers to communication
- Maintaining effective listening skills
- Assertiveness, and how it can be achieved in communication

DAY TWO

Skill 4: Teamwork

In this module, teamwork is examined for wells crew members. The focus is on key skills that help a team work well to achieve smooth task execution, safe operations and job satisfaction for team members. Team-based exercises can be used to illustrate key points or to practise relevant behaviours. This module needs to encompass team issues both within and between teams.

- Definition: (e.g. *Skills for working in a group, in any role, to ensure joint task completion, these include co-ordination, co-operation and conflict resolution*).
- Failures in teamwork leading to accidents; characteristics of high performing teams
- Who is 'the team' in a wells operation?
- Understanding one's own role within the team
- A team working model could be used to illustrate factors influencing group behaviour.
- Maintaining a 'shared mental model' across members of the team ('on the same page') and with the team on the beach/other shift/incoming (back to back) crew
- Skills for effective team co-ordination, cooperation and conflict resolution

Skill 5: Leadership

While only some wells personnel are in team leadership positions, it is suggested that this topic should involve team members, as well as supervisors. The focus in this module is on leadership and supervisory skills for managing a crew working on wells procedures and related operations. Leadership exercises with or without a team can be used to coach relevant behaviours.

- Definition: (e.g. *Skills for directing, managing and supporting a team in order to accomplish tasks for set targets*).
- Good leadership and typical problems relating to inadequate leadership
- Directing the team, what works effectively?
- Setting and maintaining standards
- Supporting the team and individual team members, especially in remote work locations
- Liaising with other onsite and offsite managers and specialists

Skill 6: Understanding performance shaping factors—fatigue and stress

Participants will gain an understanding of how performance shaping factors such as fatigue and stress (acute and chronic) can affect job performance and individual wellbeing. The module should cover how to recognise the symptoms of stress and fatigue in themselves and others, and techniques to cope with these factors.

- Definitions of fatigue and stress (acute and chronic) and how they can affect task performance
- Circadian rhythms and sleep patterns
- Causes and effects of stress at work
- Avoiding, reducing and coping with fatigue and stress

5.2 Sources of information for developing teaching materials

5.2.1. Books

Sources of information for developing teaching materials for the above modules can be found in a number of sources. A general overview of non-technical skills and advice on teaching and assessment can be found in Flin *et al* (2008) *Safety at the Sharp End: A Guide to Non-Technical Skills*. It also contains information on sources for specific skills from books, articles and websites. Background information on the CRM approach and its development can be found in Kanki *et al* (2010) or other general texts on CRM (*e.g.* for the emergency services—Le Sage *et al*, 2011). A report that provides useful background material on core CRM topics was produced by the UK Civil Aviation Authority (CAA, 2006).

5.2.2. Websites

Information on CRM training materials is available on the websites of aviation and other industrial regulators. For example:

Skybrary by Eurocontrol
www.skybrary.aero/index.php/Crew_Resource_

Management or New South Wales mining regulator
www.resources.nsw.gov.au/safety/world-leading-ohs

There are useful documents on CRM produced by the ITSR (Independent Transport Safety Regulator in New South Wales), which suggest best practice for the introduction of CRM training and its implementation in one rail company.
www.transportregulator.nsw.gov.au

The Energy Institute have a range of human factors training materials suitable for CRM on their Human Factors website and are producing new guidance on CRM training for the energy sector (Energy Institute, 2013).
www.energyinstitute.org

6. Training methods

This section outlines suggested methods for developing and delivering the WOCRM training. Recommendations, based on our knowledge of CRM in other industries, are given in **bold**.

6.1 Course delivery, duration and format

As CRM has not been generally taught in the oil and gas industry, it is suggested that in the introductory phase, that this **non-technical skills training is delivered separately from technical well control skills training**. Or, if being delivered with technical training, taught as a separate and clearly distinguishable component of a combined course. This is advised due to the need to emphasise the importance of the non-technical skills, given the increasing evidence that deficiencies in these skills are contributing to major well control accidents. While integrating technical and non-technical skills training may be a long term objective, as it is in other sectors (see CAA, 2006), the risk is that the non-technical concepts are 'lost' if embedded within technical training, especially if CRM is being delivered by technical trainers, *e.g.* on well control training courses.

The fundamental knowledge of the CRM components is normally taught in a classroom setting. It is suggested that this material is **delivered over a minimum of two days classroom time plus practice time**, normally one further day, ideally in a simulator. This length of classroom-based course is typical in aviation and in other industries (see EI report on CRM 2013) and an earlier version has been already tested in a two day classroom based course for offshore platform crew (see O'Connor & Flin, 2003). The topics can be taught in any order but the sequence given above provides a useful progression from providing background knowledge on cognitive skills to team skills to performance shaping factors that affect these skills.

6.1.1 Simulation

In addition to classroom based training to teach and discuss the basic CRM concepts, **the skills can also be practised in simulation exercises**, if simulator facilities are available (see below). The addition of realistic scenarios involving course participants will require additional time for briefing, running and debriefing of the non-technical skills (and in some cases also technical skills). As CRM training should enable trainees to learn, practise and be given feedback on non-technical skills, then classroom training combined with simulator training is an ideal combination and preferable to just using classroom based training alone. High fidelity simulation facilities are desirable but not essential for WOCRM training.

6.1.2 Delivery methods

A mixture of lectures, practical exercises and case studies can be used during classroom training. Lectures with power point slides are effective for conveying background and explanatory information on CRM concepts. Trainees can be given handouts of the slides on which to make notes and to keep as a record. These lectures can be interspersed with video clips e.g. of re-enacted accident scenarios from wells operations or other settings to identify strengths and weaknesses in non-technical skills or demonstrations of skills from other sources. **It is essential that realistic examples and cases from wells operations should be used throughout the training**. Case studies or other material from other industries can be useful to illustrate that these skills are also required (or can be deficient) in other work settings, but relevance to wells operations needs to be continuously indicated. Over-use of aviation material should be avoided. Group discussions can help to build understanding of core topics and learn from others. Individual and group exercises can illustrate particular concepts or key points. Role play can be useful for practising specific skills such as assertiveness.

6.2. Frequency of course delivery (recurrent training)

In other industries, refresher courses in CRM are provided at regular intervals and this would also be recommended for the WOCRM course. In aviation, in relation to recurrent CRM training, the UK CAA (2006, Chapter 3, p. 1) advised that:

> *"all major CRM topics should be covered at least once every three years. However, it is not essential to re-cover the whole syllabus in detail in this period. Operators should concentrate on areas applicable to their operations and aircraft types."*

This would seem to be an appropriate model for the WOCRM course for recurrent training, which could for example involve **one to two days refresher training every second or third year**, preferably in a simulator where exercises and skills debriefing could be provided.

The basic and recurrent WOCRM training **should be based on information coming from recent safety events in the industry and from the organisation's safety management system**, so that current problems, training gaps, non-technical skill requirements are identified and addressed. For example, following the fatal crash of the Air France plane (AF448) in 2010, many airlines are including new material on the effects of being startled by sudden, unexpected events in their pilots' recurrent CRM training.

6.3 Trainees

The trainees should have demonstrated competence in their required technical skills, at an appropriate level of qualification for their roles (OGP 2012b, Report 476), and at least several months of site experience as a member of a wells operations team. No prior qualifications or training in human factors would be required. Trainees may already have attended training courses for behaviour based safety courses, team training, or on other course topics may have covered some material previously and their levels of prior knowledge should be ascertained at the start of the course and the delivery paced accordingly. While very experienced wells personnel may have advanced technical knowledge and skills, it is important that they are included in these WOCRM courses given the lack of Crew Resource Management training across the industry to date.

Courses should ideally include personnel from several wells roles to foster understanding of other team members' activities, and may also include relevant off-site personnel.

The optimum number of trainees per course would be ten to twelve.

The objective of CRM training is to teach 'portable' non-technical skills which can be used by individuals in whatever team they are working in. In aviation, CRM is taught on an individual basis, as in the larger airlines pilots rarely fly with the same crews. Pilots are expected to demonstrate good CRM skills whoever they are flying with and their CRM skills are checked on an individual basis, within a team context. As wells operations personnel do not always work in the same crews, then this model of individual portable skills is particularly suitable and justifies training individuals who do not normally work together in one course. Therefore in WOCRM courses, trainees could be from different crews (which can be useful for learning across installations/companies) or all from the same crew. The latter is similar to team training where an established team, prepare for and/or practice, working together but this team-based method is not the conventional approach to CRM training.

6.4 Instructors

The **WOCRM instructors will require a basic knowledge of the non-technical skills and of the human factors concepts to be taught on the course**. In some industries, they are called CRM facilitators rather than instructors, to indicate that they are

not human factors experts but technical specialists trained for this task of working on CRM with a peer group. They should have technical knowledge of wells operations and well site experience, this combination of specific technical skills, with additional skills in training human factors, is the model used in other industries, where technical specialists with specific training in teaching CRM usually deliver the courses. Ideally the WOCRM trainers should come from the wells industry, from training or technical departments within companies or from wells specialist independent providers. This means there will be an initial industry requirement for 'train the WOCRM trainers' courses.

For guidance from other sectors on training technical specialists to be CRM trainers, the UK Civil Aviation Authority (CAA) has produced a set of standards criteria for a pilot to be an aviation CRM instructor (CAA, 2009). Some operating and drilling companies now employ human factors professionals, such as psychologists, and they would provide an ideal resource for CRM training development and co-delivery, in conjunction with technical specialists, particularly in the early stages of course design. Where observation and feedback of nontechnical skills from simulation exercises is included in the training for formative (non-jeopardy) assessment, then the instructors should also be trained in behavioural observation and rating. Again this component of the courses can be conducted by technical specialists along with behavioural scientists, until technical trainer proficiency levels are established.

Alternatively, there are a number of commercial training providers who deliver Crew Resource Management courses, the most experienced of whom will be trainers of aviation CRM or maritime courses, for example, Bridge Resource Management (BRM) or Engine Room CRM (ECRM) or similar (*e.g.* nuclear plant crews). However, while these trainers may be knowledgeable about CRM, some care should be taken when using this type of provider to ensure that they have sufficient expertise in wells operations to customise their standard CRM course to suit the particular technical demands of this industry.

6.5 Course evaluation

As with any training course, there **should be an evaluation** of how the training is received and if possible whether the knowledge and skills are transferring to the workplace. Advice on training design and evaluation can be found in Goldstein and Ford (2002). Methods of CRM training evaluation are discussed in CAA (2006, chapter 8), Kanki *et al* (2010) and examples of methods of CRM training evaluation can be found in Flin *et al* (2002a).

6.6 Role of simulation

CRM training does not simply consist of simulator exercises and feedback. However, where simulation facilities are available, for example at existing well control schools, these can be extremely valuable for trainees to practise and receive feedback on non-technical skills when working on relevant technical operations. Pilots have regular simulator training to complement their classroom CRM training, often referred to as LOS (Line Operational Simulations) or LOFT (Line Operational Flight Training), for details see Kanki *et al*, 2010, chapter 9).

Scenarios can be written to create wells operations situations that require particular non-technical skills, and the players in these events can be debriefed by the facilitators or by other course members. Company or industry accident and near-miss databases can provide valuable examples for scenario writing. Where CRM training takes place in a training centre with simulation facilities, then classroom modules can be interspersed with illustrative scenarios in the simulator.

6.7 Assessment issues

While informal or formative feedback is very valuable where non-technical skills are practised during a CRM course, **formal or summative (pass/fail) assessment of CRM/non-technical skills should be separated from the WOCRM training programme**. Particularly

in the early phase of introduction of WOCRM to the wells community, trainees should feel confident that they can practise CRM skills in simulation exercises without fear of penalty. Trainers giving feedback need to be competent in observing and rating behaviour, and may require specific training in this type of debriefing skill. Web-based courses are being used for debriefing training in other sectors *e.g.* the DASH course at the Harvard Medical Simulation Centre (www.harvardmedsim.org/debriefing-assesment-simulation-healthcare.php)

Formal assessment for qualifications or licences requires competent and qualified assessors, a validated assessment system, professional acceptance and appropriate organisational systems for preparation of candidates and procedures for dealing with failures. Assessment was not part of the remit of this project, and so is not discussed further. See Flin *et al* (2008) or CAA (2006) for further discussion of the issues relating to formal evaluation of non-technical skills.

6.8 Transfer of WOCRM training to the workplace

What is essential for any training course is that the skills being taught in the classroom and the simulator are transferred to the workplace. For a behavioural skills course such as WOCRM, the level of transfer will depend on the prevailing organisational culture at the worksites. That is, the extent to which fellow workers, managers and supervisors encourage or discourage the particular behaviours, such as speaking up, maintaining standards or supporting other team members. The training instructions have to be reinforced at the worksite, where observation and constructive feedback on well crew members' non-technical skills should become part of the normal way of operating at the worksite. The language of CRM should become part of everyday work site discussions *e.g.* when there is a particular need to maintain high situation awareness. Some recent examples from the early introduction of CRM training to UK healthcare teams shows how important the worksite culture is to the maintenance of the CRM behaviours (McCulloch *et al,* 2009). That is, any new, safer behaviours will be discontinued if they are not encouraged by peers, supervisors and managers.

This is an area of responsibility for the companies employing wells personnel and it indicates that on-site managers and supervisors require WOCRM training, and more senior managers have to give their visible support, in terms of time and resources, to this initiative.

6.9 The role of WOCRM in a Safety Management System (SMS)

The WOCRM course, as with other safety training, should form part of the organisation's Safety Management System. As mentioned above under recurrent training, the course content should be informed by an ongoing human factors analysis of task performance during well operations, especially in relation to the detection and management of control problems. Valuable information on work site behaviours and conditions that need to be included in a CRM course can be gleaned from incident reports, near miss data, simulator training observations, and other kinds of operational audits. In a review of human factors in drilling operations, it was noted,

> "*During the analysis of historical data, it became clear that Human Factors data is not being recorded. It is recommended that these data be recorded on all incidents and near misses if headway into understanding Human Factors contributions is to be made. This would require a change in the emphasis placed upon incident investigation, to gain the co-operation of people rather than encouraging them to close ranks*" (Wilson & Stanton, 2001, p. 21).

Such analyses can provide essential data for feeding into both WOCRM classroom training and scenario exercises in well control. This linkage to the Safety Management System is an important element of CRM training in aviation (see EI CRM report, 2013).

7. Conclusion

The aim of this project was to develop a recommended syllabus for Crew Resource Management training customised to the needs of Well operations teams (*i.e.* performing drilling, completion, intervention & work-over operations). Following a review of the literature and an interview study of wells personnel, it was concluded that the basic six categories of non-technical skills, (situation awareness, decision making, communication, team work, leadership and awareness of the effects of stress and fatigue), should form the main course modules. A suggested syllabus indicating the component skills within these categories and background material was outlined set in the form of a two-day course programme. Issues relating to course format, trainees, trainers and organisational issues were also discussed.

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Appendix 1. Interview schedule

Introduction, confirm purpose, anonymity, consent, *etc*. It is accepted that you may have a number of different tasks and locations for your job. This interview is going to ask you about your work when engaged in or with a crew on an ongoing wells operation, such as drilling. We are interested in all the things that people in your job need to think about and to do for a wells operation to proceed smoothly, efficiently and safely.

Confirm job experience etc

Instruction

Think of a day at work when you were working on a more challenging wells procedure (possibly where something did not initially go to plan or there was unforeseen problem or it could have been a shift where you and/or the crew worked particularly well). **Tell me about who was there and what was happening from the start of the event.**

[**If prompt needed,** examples could be: experiencing a kick, shallow gas, bad weather (not the weather itself but its effects—on the drilling procedure, equipment or mechanical failure, such as dropping a piece of equipment)].

Case Related Questions

1. What did you do to make the procedure go well?
2. Who else was essential to that procedure? How did you work with them to make the operation a success?
3. Did you learn anything which would make you do things differently in a future challenging situation? If so, what?

General Questions

4. Briefly describe what your main jobs are during a typical day.
5. What kinds of decisions do you have to make during wells/ drilling operations?
6. If someone makes a decision but you disagree with it, what would you do?
7. How do you keep track of what is going on during the job?
8. What kinds of things can affect the working atmosphere within your crew?
9. How do you tell other people you are working with what is going on and what you are doing?
10. Describe the kinds of things you have to look out for during your shift or a particular job you are doing?
11. What sorts of things might alert you that things are not quite right?
12. What does it feel like when you are part of a crew that is working especially well together/ not well together?
13. Any other comments about your job, safety at work, teamwork?

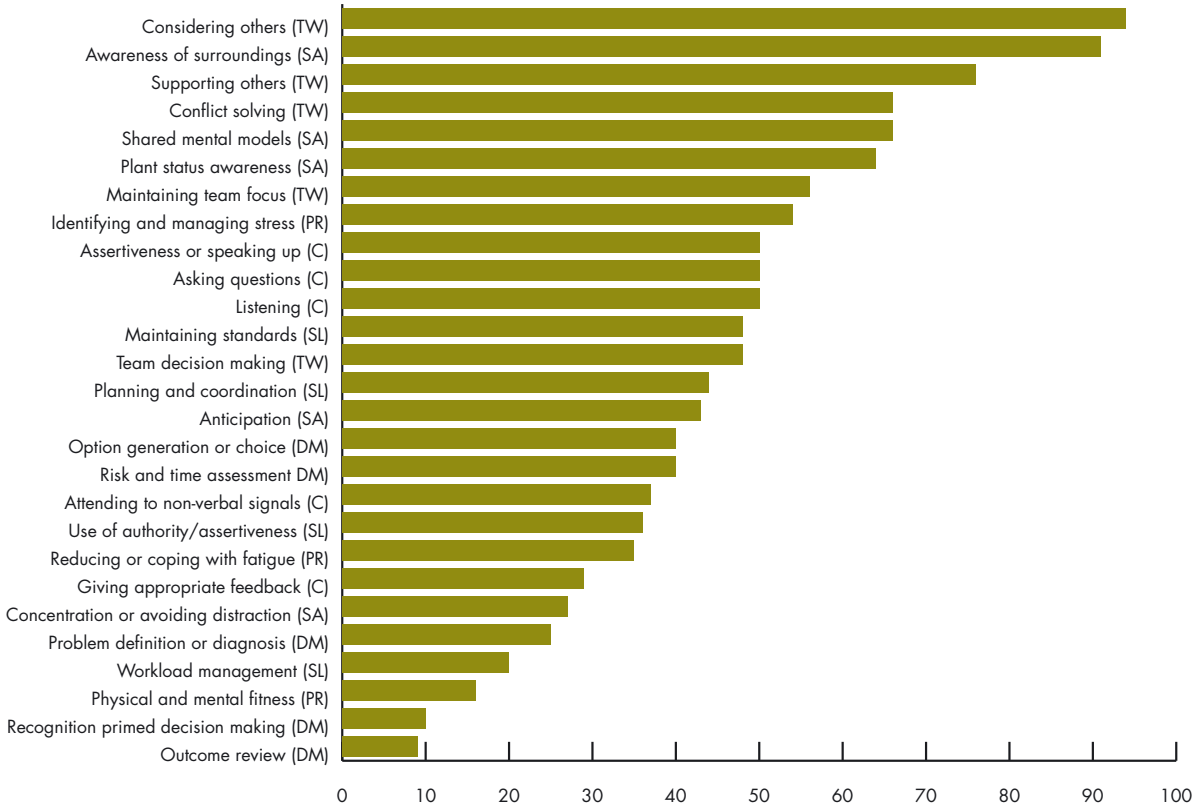
Appendix 2. Coding framework

Offshore operations non-technical skills framework (Flin *et al*, 2002a).

CATEGORIES	SKILLS
Situation awareness	• Plant status awareness • Work environment awareness • Anticipation • Concentration/avoiding distraction • Shared mental models
Decision making	• Problem definition/diagnosis • Risk and time assessment • Recognition Primed Decision Making/Procedures/Analytical • Option generation/choice • Outcome review
Communication	• Assertiveness/speaking up • Asking questions • Listening • Giving appropriate feedback • Attending to non-verbal signals
Team working	• Maintaining team focus • Considering others • Supporting others • Team decision making • Conflict solving
Supervision/leadership	• Use of authority/assertiveness • Maintaining standards • Planning and co-ordination • Workload management
Personal resources	• Identifying and managing stress • Reducing/coping with fatigue • Physical and mental fitness

Appendix 3. Coding frequencies across the data

Figure A-3: Coding frequencies across the data



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