Safe staffing levels: latest Energy Institute guidance

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The Human and Organizational Factors Committee (HOFCOM) of the Energy Institute (EI) are developing new guidance on ensuring safe staffing levels. The objective is to provide clear and concise guidance to help companies in the petro-chemical and allied industries to determine appropriate levels of staff. This guide builds on the Energy Institute's "Briefing Note 23 on Workload and Staffing levels". The guidance addresses both normal operations and emergency response as well as different stages of operational lifecycle (commissioning, steady state operations and decommissioning as well as other modes of operation e.g. as in the power sector) and account for factors that impact upon staffing levels such as competence, supervision, and scheduling. This publication is for use by people responsible for determining the approach to assessing staffing levels such as business team managers, human resources, maintenance and operations leads, project managers and planners, as well as safety and regulatory persons.

Introduction

Ensuring you have an adequate number of competent people available when required to perform safety critical tasks is a key element of assuring safe operations. Operational problem solving, decision making, judging, analysing, remaining vigilant and performing tasks all require having a sufficient number of competent people available when and where required. In the case of team tasks, tasks need to be shared, including those required for maintaining situational awareness, assessment and joint decision making. Management and supervisors must be capable of supervising operations as well as providing direction, leadership and supporting continuous improvement. For human performance to be optimised, staffing numbers need to be sufficient, roles need to be well defined and individuals need to be competent.

A key method that has been cited for use in supporting staffing arrangements is the CRR348/2001 "Entec" methodology" (Brabazon and Conlin 2001) This method, developed under commission to the United Kingdom Health and Safety Executive, has been advocated and applied within process operations. This is sometimes called the Entec "ladder and tree model". Its application is supported by the EI's Safe staffing arrangements - User guide for CRR348/2001 methodology (Energy Institute, 2004). Feedback from members of HOFCOM was positive with respect to its practicality and usefulness.

However, the latter EI 2004 guide is limited to this single method. There are many other methods that can be used to inform decisions on staffing levels, such as NASA-tlx.

In addition, the "ladder and tree model":

- Is limited to control room/panel staffing needs for identifying and responding in the control room to alarms/incidents.
- It does not aim to support other safety critical support roles, such as maintenance, field operators (e.g. for inspection of leaking equipment) or emergency response staff (e.g. onsite fire fighting or emergency response teams or a team based prolonged control room emergency response).
- It does not aim to consider operational needs beyond identifying and responding to alarms in the control room.
- It does not necessarily factor in requirements relevant to determining staffing levels, such as shift structures, allowance for non-operational activities, staffing resilience and succession.

Therefore, HOFCOM requested the development of a new guide. The new guide aims to support:

- Understanding the importance of adequate staffing levels to safe operations;
- Selecting assessment methods for determining staffing levels;
- Recognising associated issues of shift systems and numbers of supervisory staff;
- Specifying and designing staffing level risk controls (management of change, use of organisational baselines, fatigue risk management etc):
- Determining 'As Low As Reasonably Practicable' (ALARP) staffing levels.

This guide aims to support the selection of assessment methods and provides references to method specific guidance. High level guidance on specific methods is given in Annexes. The cited references may be required in order to apply the specific methods.

This guide provides generic advice applicable across different types of energy and related industries and both small and large businesses. Each business needs to develop its own specific policies and procedures.

Staffing levels

Staffing levels refers to the number of Suitably Qualified and Experienced Persons employed to perform and control activities throughout the life cycle of the plant and in all operational states. Ensuring you have an adequate number of competent people available when required to perform safety critical tasks is a key element of assuring safe operations. Some key terms are noted below:

- Staffing level - Staffing level is concerned with ensuring the correct number and type of personnel are in post for all tasks.
- Safe staffing - Having the right number of people, with the right skills, in the right place at the right time.

- Workload - Workload can refer to the physical or mental effort required to carry out a task.

Related Energy Institute guidance

This Energy Institute guide focuses on determining safe operational and maintenance staffing levels for both normal operations and emergency response as well as different stages of operational lifecycle (commissioning, steady state operations and decommissioning). It also notes links to related issues of shift structures, levels of supervision and competence, and risk controls such as task simplification, succession planning and job design. The risk of fatigue due to inadequate staffing levels is included where this impacts process safety.

This guide may be read in conjunction with other Energy Institute guidance, including:

- Human factors briefing note no. 11 – Task analysis;
- Guidance on human factors safety critical task analysis;
- Safe staffing arrangements - User guide for CRR348/2001 methodology;
- Training and competence – Human Factors Briefing note 7;
- Supervision – Human Factors Briefing Note 21;
- Fatigue – Human Factors Briefing Note 5;
- Organisational change – Human Factors Briefing Note 3.

Case studies of major incidents

The guide commences with major accident case studies to illustrate how staffing levels and related arrangements can contribute to major accidents, and draws out the key lessons learnt from these case studies on why organisations can get staffing levels wrong. Three examples are shown in Figure 1. Examples of major accidents cited in this guide include instances of:

- Chronic fatigue amongst operators due to working 12 hour shifts for 30 days;
- A single operator responsible for three complex process units;
- Centralisation of specialist resource away from a site contributing to failure to understand and control an incident;
- Insufficient staff to assess and resolve process safety hazards.

Lessons learnt

These case studies show the effect that high workload and inadequate staffing can have human error, fatigue and decision making. In the event of time critical tasks, inadequate staffing levels can lead to individuals being overloaded with information, decisions and tasks, leading to error and delayed reactions. In the event of an incident, operators and maintainers may need support from supervisors, technicians and engineers to understand and respond. Low levels of support can contribute to failures to correctly interpret faults and select effective responses.

The case studies also indicate that fatigue is related to:

- Staffing levels leading to staff being fatigued by the intensity of work and working hours;
- Shift systems and shift durations conflicting with sleeping patterns;
- The failure to take account of auxiliary duties, such as administrative tasks, leading to an underestimation of role workload, contributing to excessive working hours and workloads.

Fatigue is a well-documented and well understood phenomenon that can contribute to human error, especially in decision making and task execution such as slower reactions, memory lapses, reduced attention etc. (Mehta and Peres, 2016. Strauch, 2015).

Figure 1: Major incidents related to staffing levels

The 2005 Texas City refinery explosion occurred during the start-up of the isomerization (ISOM) unit, killing 15 people and injuring 180.

"…the CSB concludes that fatigue of the operations personnel contributed to overfilling the tower" (CSB, 2007, p.289). Several key operational staff had worked between 29 and 37 consecutive 12-hour shifts.

Esso Longford gas plant explosion 1998. Two people died, eight were injured and gas supplies to the state of Victoria were cut off for two weeks. (LRF, 1999)

Engineers had also been relocated away from the site.

On January 23rd 2010 at approximately 09:35am, oil tankship Eagle Otome collided with the general cargo vessel Gull Arrow at Port Arthur, Texas.

Starboard side of the Eagle Otome, with the Kirby 30406 lodged in it (image copied from NTSB, 2011)

The NTSB (NTSB 2011) report indicates the collision was caused by the first pilot's untreated obstructive sleep apnea and his work schedule, which did not permit adequate sleep, extended wakefulness, disrupted circadian rhythm, and distraction from conducting a radio call.

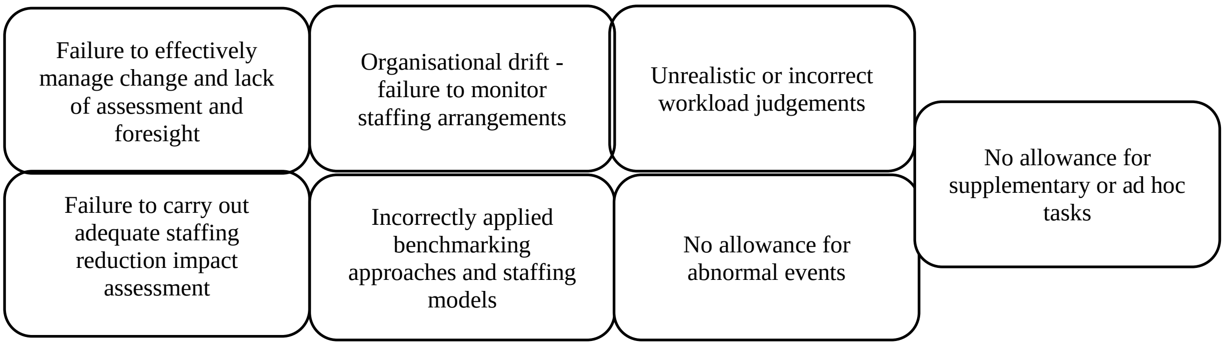
Why do some organisations get staffing levels wrong?

The aforementioned case studies and feedback from industry stakeholders indicates that organisations can get staffing levels wrong due to a lack of assessment and literal application of staffing benchmarks due to, as elaborated below in Figure 2.

Key reasons include a lack of awareness of risks or ineffective management of change arrangements. Also, there are a number of benchmark approaches to determine staffing arrangements, such as using the staffing arrangements at a similar facility as a benchmark for another facility. The literal application of these models may lead to facility specific and function specific staffing needs being overlooked.

Staffing arrangements are sometimes determined by a judgement of requirements based on observation of past or current operational performance. Operational experience may not include periods of abnormal events, such as when equipment fails, peak demand, production interruptions or emergency events. Staffing levels based on an unqualified judgement of the workload required of tasks may fail to take account of, for example, true task completion times or do not allow for slower task completion times of less experienced staff.

Figure 2: Why do some organisations get staffing levels wrong?



Early recognition of staffing issues

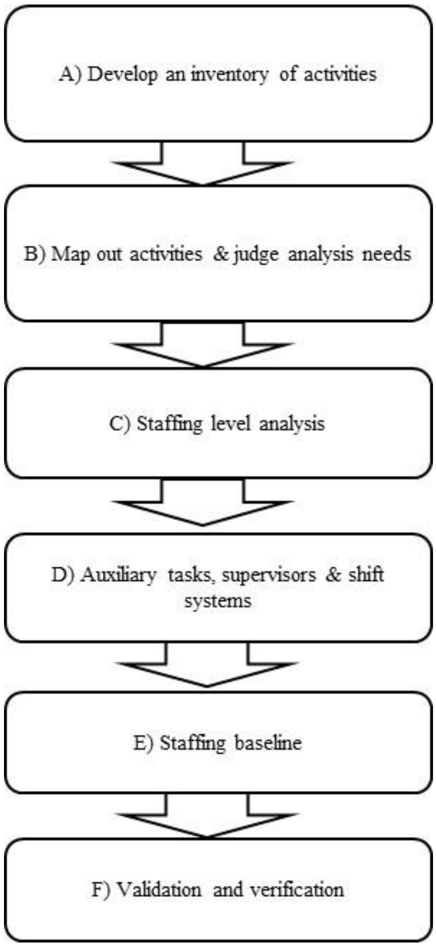
The early recognition of staffing issues allows due diligence to be applied to assessment and planning. Table 1 provides a checklist to support identification of potential staffing issues. The guide includes a checklist for recognising potential staffing arrangement issues, such as Removing layers of management or supervision, Changes in shift systems or working hours and Relocating staff. These may then be risk rated and screened for further assessment.

Staffing level issues may be identified by the use of monitoring indicators, such as increases in over time. These indicators would be tracked in real time and reviewed on a monthly or quarterly basis. In the event that an adverse trend is noted, this would be investigated to determine if the trend relates to staffing levels. the root cause assessment of incidents may also indicate that staffing level issues, such as fatigue, task overload or human error may have contributed to incidents and thereby prompt a review of staffing levels.

Assessing staffing levels

Figure 3 provides an overview of the sequence of assessment, lettered A to F, that can be performed to specify a safe staffing level. The same approach and principles may be applied to existing and new plant. However, the assessment for new plant may be less certain and will be reliant on designers' and engineers' judgement of operational demands. Also, new plant may require a higher level of physical exercises or trials, such as during commissioning, and updating of staffing assessments as and when plant design and operational demands become clearer. The guide annex provides worked examples of applying this approach.

Figure 3: Overview of staffing level assessment



A. Producing an inventory of activities

A first step can be to produce an inventory of activities from "bounding scenarios", such as a list of emergency scenarios, peak operational activities, plant commissioning etc. Where an entire plant is being assessed, this may commence with a high-level workflow of the entire facility.

B. High level activity map and determining assessment needs

Upon developing an inventory of activities, each of these may be mapped out using work process / activity mapping, to scope further assessment and the form of staffing level analysis in step C.

C. Assessing the staffing level per activity

Step C involves selecting and applying a form of assessment suitable for the activity.

D. Factor in auxiliary duties, supervision and shift systems

Upon determining activity specific staffing needs, the demands of auxiliary tasks, shift systems and supervisory need to be added in.

E. Staffing (organisational) baseline

The results of assessment can be aggregated to create an inventory of all the posts required for safe operations and maintenance, along with the qualification and experience requirements per post.

F. Validation and verification

An option is to validate and verify safe staffing claims, such as by the use of Human Based Safety Claim Substantiation or an independent review of staffing arrangements against recognised good practice and validation of the feasibility of safety claims.

Step A: Producing an inventory of activities

There may be numerous tasks and activities performed at an operational facility or unit. An option is to limit the extent of assessment by identifying and defining a sub-set of operational "scenarios" that will be used to determine and test staffing levels. may be drawn from existing safety assessments, descriptions of operational processes / peak operational workloads High level activity map and determining assessment needs. These may be termed "bounding scenarios".

Step B: High level activity map and determining assessment needs

Upon concluding a bounded inventory of activities, each of these may be mapped out using work process / activity mapping. This tends to involve producing graphical flowcharts of sub-activities. The determination of assessment needs refers to step C and the level of task safety criticality.

Step C: Assessing the staffing level per activity

Assessment of staffing levels per activity does not necessarily involve detailed analysis. The extent and form of assessment depends on the complexity and safety criticality of operations. Consultation with members of HOFCOM and a brief survey of current practice identified a range of methods that have been used in practice in the energy industry and the type of assessments they have been used for. This was used to produce a list of assessment methods and guidance on their application.

In the case of simpler activities and those for which there is established operational experience, it may be possible for Subject Matter Experts (SMEs) (i.e. current staff) to judge staffing levels from operational experience without any further assessment. For example, a central control room may control two moderately complex process units, each with a separate control panel requiring simultaneous operations, and hence judged as a minimum of two operators from past or similar operational experience.

Where judgement alone is insufficient for a simple task, it may be possible to determine staffing levels for simple tasks and activities by the use of task and / or timeline analysis (Energy Institute, 2011).

Task Analysis can be used to explore the relationship between aspects such as; task activity type (e.g. communication, action, checking, retrieving information). The tasks may be split between roles (such as operator 1, operator 2, maintainer, supervisor) location (control room, terminal) equipment (interface, valve, tooling) and across time. This helps to inform whether tasks are simultaneous and physically co-located or not.

Timeline analysis is to chart the chronological order of events and sequences of operations, and the duration of each of the various tasks to determine when they should occur. The resultant charts can be mapped to individuals and / or teams for the sake of staffing level assessment or task planning.

The assessment may also ask SMEs to view the mapped out tasks and group them into roles on the basis of key task attributes

- Splitting tasks that are simultaneous and cannot be performed in parallel by a single person;
- Determining the competences required per sub-task and matching these to appropriate roles
- Noting any safety requirement for task independence, task checking and supervision.

For more complex activities, especially cognitive tasks it may not be possible to judge staffing levels using simple task or timeline analysis alone. In this case, a formal analysis of task workloads may be needed, and methods exist that enable this to be done. Common examples of methods that have been used in the energy industry for assessing workload include:

- Subjective Workload Assessment Technique (SWAT, Reid et al 1988);
- National Aeronautics and Space Administration Task Load Index (NASA TLX, 2018);
- Team Workload Assessment (Lin et al, 2011);
- Alarm Metrics, The Engineering Equipment and Materials Users Association, (EEMUA, undated);
- Visual Audio Cognitive Pychomotor (VACP, Mitchell 2000);
- Crisis Intervention and Operability Analysis (CRIOP, Johnsen et al. 2008);
- Entec ladder and tree method (Brabazon and Conlin, 2001).

These methods are usually preceded by a task and / or timeline analysis. These methods tend to provide a rating on task attributes such as mental workload and time pressures. After rating a task, a judgement may be made whether the task needs to be split or shared in order to reduce individual workload to a medium or lower level.

It should be noted that these methods do not indicate what staffing levels should be. They do provide an indication on whether cognitive workload is high and presents a risk. The assessors need to apply judgement or perform further assessment of options to decide on appropriate interventions such as:

- Automating tasks;
- Reducing workload by shedding non-safety or time critical tasks;
- Reducing distraction;
- Providing more staff.

For current or new activities, analysis may not be sufficient due to uncertainties about how the task is performed, for example: the time and effort required to carry out the task, the dynamic nature of a task or the abilities of staff. In these cases, a physical or desktop exercise may be needed to help assess the proposed staffing level.

Step D: Factor in auxiliary duties, supervision and shift systems

The latter step C methods are task focused. It is advised that upon determining task staffing needs, the demands of auxiliary tasks, shift systems and supervisory need to be added in. An estimate of the time required for these auxiliary activities is essential to accurately determine what staffing level allowance is required. In this example, these auxiliary activities may equate to (say) 25% of each person's time, equivalent to one additional person per operational task, i.e. 25% of four people. The latter analysis can be referred to as Job Workload Analysis.

In addition, there may be specific and non-specific supervisory staffing needs. There is extensive guidance (SDF, 2014) on good practice in terms of the "span of control", namely the number of staff that any one supervisor or manager may feasibly manage, i.e. the ratio of staff to supervisors or team leaders. This tends to link the number of people reporting to any one supervisor, team leader based on factors such as task complexity and safety criticality.

Task and workload analysis may indicate the number of people needed for operation. In the case of a shift based operation, the number of staff needs to be a multiple of staffing per shift. The duration of the shift and shift intervals will obviously determine the number of shifts and hence the staffing level.

Step E: Organisational / staffing baselines

The results of assessment can be aggregated to create a "staffing baseline", termed an organisational baseline in the UK nuclear industry or a "minimum staff complement". This is an inventory of all the posts required for safe operations and maintenance and may be used to identify and control changes to staffing.

A baseline may identify all safety critical posts required for:

1. Operational and maintenance staff, such as control room operators, electricians, tanker drivers and laboratory technicians, who perform safety critical activities;
2. Supervisory and managerial staff who administer, supervise, oversee and control safety critical activities, sometimes termed "the controlling mind";
3. Managerial and director staff who develop and lead policy, culture and govern safety management systems as well as provide an intelligent customer capability

A staffing baseline may be used to identify changes that impact safety critical activities and to test their impact on staffing requirements, as well as an ongoing safe staffing management tool for controlling (for example) staff retirement and resignation. The baseline may be in the form of a dynamic database and is typically site or facility specific, maintained and administered to ensure it remains current and is used to control safe staffing levels and identify vulnerabilities. It is good practice to:

- Define a target proportion of staffing baseline to be met, such as 90%, allowing for churn in staff and for periods where staff are developing experience and training before being fully SQEP;
- Monitor the duration of concessions for staff not fully SQEP, such as what proportion of staff in baseline posts have a SQEP concession for (e.g.) over 6 months and how many for over 12 months;
- Track fulfilment of the baseline over time to identify trends.

Step F: Validation and verification

An option is to validate safe staffing claims where required. Verification and validation are usually qualitative. In the case of staffing levels this may draw on the principles of Human Based Safety Claim Substantiation and comprise checking:

- Have all safety critical tasks been considered?
- Have suitable bounding scenarios been noted?
- Has a suitable form of activity or task analysis been applied?
- Has the potential for human failure been adequately considered?
- Whether realistic fatigue (human endurance) assumptions have been made in the specification of working hours and shift systems?
- Whether realistic assumptions and reliance has been placed on staff competence and supervisory support?
- Whether realistic assumptions have been applied for auxiliary duties?

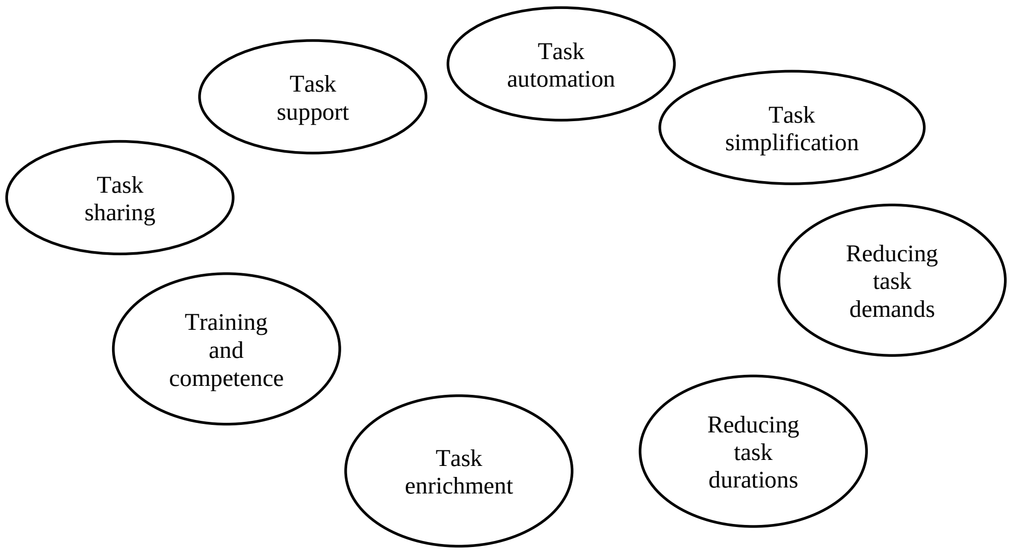
The importance of verification and validation will be higher for the more safety critical activities and where there is greater uncertainty in the assessment, such as for new tasks and processes.

Staffing levels risk controls

Where an assessment identifies a high workload for a discrete task that cannot be addressed solely by adjusting staffing levels, then there are a number of options to consider, outlined in Figure 4. These options can also be considered for low workload. Some examples include:

- Task support - Better design procedures and job aides (using more images and diagrams) may help people undertake work more quickly.
- Task simplification - Issue permit to work for a specific (low risk) area of the plant which has fewer safety requirements than if the permit of work was issued for all areas, including ones with greater safety requirements.
- Reducing task demands - For example, rationalisation of alarms so that nuisance or unwanted alarms that require an operation response are removed.

Figure 4: Staffing levels risk controls



Monitoring indicators

Table 1 provides a typical set of staffing level indicators. Many of these may already be collected and can be drawn on to identify any adverse staffing level issues. Figure 5 provides an example of a staffing indicator. The example follows on from the idea of a staffing baseline. For example, on a site with 200 safety critical posts, 93% of these posts were filled at the start of the period, declining to 85% in July before rising back up to 92% in December.

Figure 5: Example organisational baseline tracker

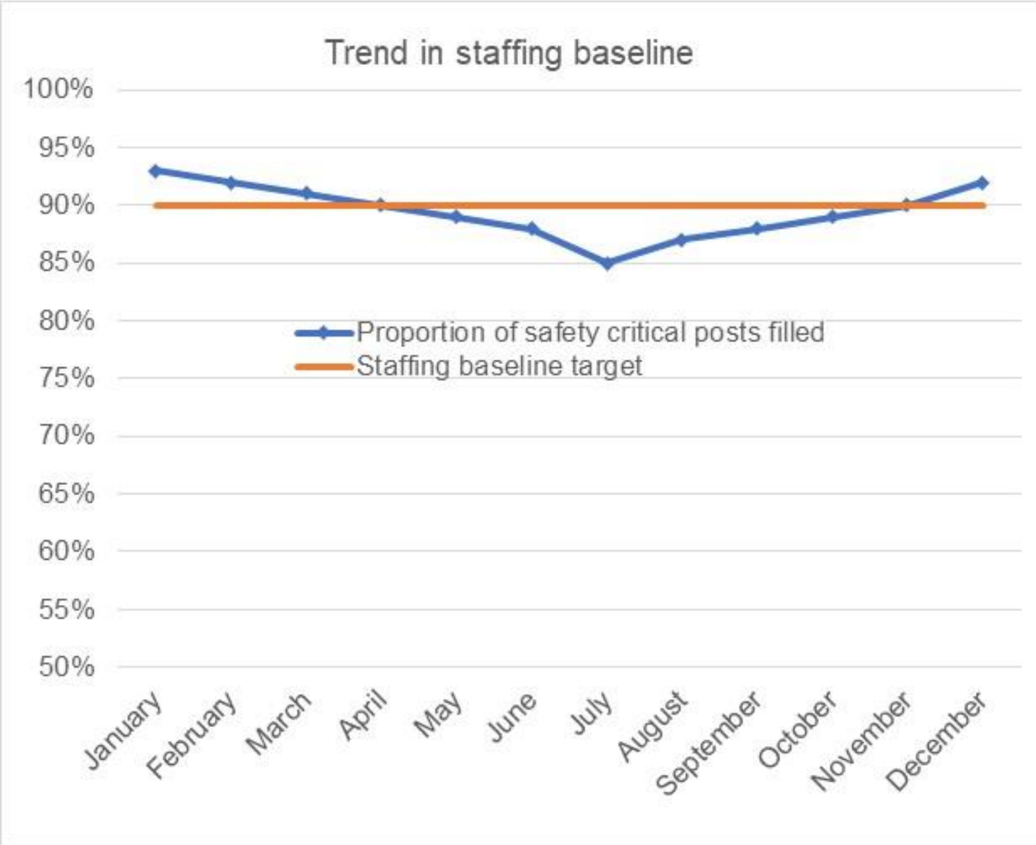


Table 1: Staffing level related indicators

Overtime worked, such as proportion of staff working over 48 hours per week.
Unfilled safety critical posts (gapped posts)
Proportion of safety critical roles performed by contractors.
High unplanned use of temporary contractors to fill posts.
Number of singletons (where only one person is employed for a safety critical role)
Safety culture assessment results
Staff turnover
Stress related absence
Stress surveys reporting workload related stress
Work tasks not completed to schedule, such as maintenance backlogs and outstanding actions
Human error related to competence or workload / fatigue
Proportion of changes in safety critical posts submitted to Management of Change approval process.

Real time monitoring and control of fatigue

In the case of safety critical roles, it is good practice to have real time monitoring and control of working hours, especially where this involves shift systems or significant over time. This may be termed "Fatigue Risk Management". The Energy Institute guide on "Managing fatigue using a fatigue risk management plan (EI, 2014)" may be applied. This defines a FRMP as:

> "… a risk-based plan or system of controls that identifies, monitors and manages fatigue risk, with the aim of ensuring that, so far as reasonably practicable, employees are performing with an adequate level of alertness." (p17).

This may include:

- Defining a formal policy of minimum rest periods and sleeping time between shifts;
- A statement of what acceptable limits are for example, the maximum number of hours of work for a standard day and the maximum number of hours of work before a break should be taken.
- Defining triggers, such as the above, for acting on individual working hours, in real time;
- Real time recording of working hours and rest periods and sleeping time between shifts for each employee;
- Guidelines on what staff and supervisors / managers should do if they think someone is too tired to work safely.
- The inclusion of fatigue in health and safety training, including recognition of the signs and symptoms of fatigue (see Table 2) enabling recognition of fatigue or overload in self and in others, and empowering staff to manage their fatigue and challenging others' fatigue.

Table 2: Signs and symptoms of fatigue (CCOHS, undated)

• Weariness. • Tiredness. • Sleepiness, including falling asleep against your will ("micro" sleeps). • Irritability. • Reduced alertness, concentration and memory.	• Lack of motivation. • Depression. • Giddiness. • Headaches. • Loss of appetite. • Digestive problems, and • Increased susceptibility to illness.

Achieving ALARP

The 'evidence' for judging whether risk has been reduced "as low as reasonably practicably" (ALARP) by suitable staffing levels tends to be in the form of:

- A qualitative demonstration that all staffing risks have been adequately assessed and
- Relevant good practice has been applied to control identified risks.

The guide provides a set of questions for assessing the achievement of ALARP for staffing levels, such as:

- Has a sufficient range of bounding scenarios been identified and defined, covering all significant operating modes and conditions, such as process upsets, commissioning, degraded operations and emergencies?
- Has allowance been made for role workload in addition to task workload, such as auxiliary administrative tasks, training and covering for absence of other staff?

An example assessment

The guide includes seven real case studies of how staffing levels were assessed. One example is given below.

Description

A facility was being decommissioned. The number of staff was being reduced in accordance with the termination of operations and decommissioning of operational equipment. A requirement remained to have a water supply at all times. If the normal water supply was lost, such as due to power failure, pump failure or fracture of a pipe, then an emergency water supply had to be connected. This would involve retrieving flexible hoses, laying the hoses to an emergency valve, connecting the hoses, starting up back up generators and pumps to raise pressure and opening the emergency valve.

Identifying and screening staffing issues

The downsizing of a workforce reduced the number of operators per shift. A question was posed whether an emergency supply of water could be connected on time (within one hour) in the event of an incident. It was unclear whether sufficient staff remained in post to perform the emergency water supply connection in the target time. As a safety critical emergency response task this would be screened as a High-risk issue.

Producing an inventory of activities

Consultation with safety engineers identified key tasks to include:

- Detection and recognition of loss of normal water supply:

- Mobilisation of team to connect alternative water supply;
- Operation of back up generators to power the pumps to initiate water supply.

High level activity map and determining assessment needs

Due to the requirement to perform the task in a specific time, the involvement of two teams in different locations (control room operators and a team of field engineers), it was judged that timeline analysis would be appropriate. The tasks were considered simple in respect of mental workload and high in respect of physical demands of moving and connecting hoses.

Assessing the staffing level per activity

A timeline analysis was developed that mapped out the sequence of tasks required and task completion times per team member. The availability of staff (with suitable competence) to perform tasks, including simultaneous activities was tested by placing posts against the tasks. The task steps were drawn from review of emergency procedures and consultation with operators. Task locations were taken from site diagrams. Task completion times were estimated from a desktop walkthrough of the tasks.

Verification and Validation

Verification entailed a desktop demonstration of posts aligned to a timeline of tasks.

Staffing level risk control

A minimum staffing level of designated posts (control room and field engineers) was defined to assure ongoing emergency response capability.

Staffing level indicators

The continued employment of the minimum designated posts was used as an indicator.

Conclusion

Organisations, especially those with high hazard operations, should take a planned and systematic approach to assessing, determining and managing staffing levels. The level of assessment and management needs to match the safety criticality, complexity and uncertainty of the specific operation. Staffing levels need to be informed by an assessment of operational and maintenance requirements.

The staffing level should ensure that there is a sufficient number of Suitably Qualified and Experienced Persons (SQEPs) employed to perform and control activities throughout the life cycle of the plant and in all operational states, such as process upsets and emergencies, with the risk of fatigue and human failure reduced as a low as reasonably practicable. This staffing level should make allowance for auxiliary (non-operational) duties such as administration, annual leave and sick leave, peak workloads, the impact of shift systems, the need to support less experienced staff and succession management.

This guidance will provide an overview of recommended good practice within the energy industry on how to assess and assure safe staffing levels, supported by practical examples and detailed advice on the selection of assessment methods.

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