ASSESSING THE SAFETY OF PROCESS OPERATION STAFFING ARRANGEMENTS

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Demonstration is a core requirement of the UK Control of Major Accident Hazards (COMAH) Regulations and duty holders are required to demonstrate the adequacy of their safety arrangements including process operation staffing . The operation of a major hazard site must incorporate adequate safety and reliability (COMAH Schedule 4 3(b)). Process operation staffing and the technical measures available to operators have major impacts on the ability to control upsets, prevent major accidents and minimise disruption to production. A method has recently been developed by Entec on behalf of the Hazardous Installations Directorate (HID) of the Health and Safety Executive who have observed that a number of oil, gas and chemical sites are taking steps to reduce staffing levels in their operating teams. There is a concern that such reductions could impact the ability of a site to control abnormal and emergency conditions and may also have a negative effect on staff performance through an impact on workload, fatigue, etc. Although sites are often doing risk assessments on aspects of their staffing arrangements through task analysis and other existing techniques, problem areas are being overlooked. The aim of the project was to develop a structured assessment method which systematically covered all the relevant issues and would prevent potential problems in process operation staffing arrangements being missed. The method was developed through collaboration with industry and HSE and provides a systematic approach which structures people's thinking about the factors which need to be considered when assessing the safety of process operation staffing arrangements. The method is already being used on several sites in full studies. Some sites are using it to assess current staffing arrangements, some are using it to assess the impact of a planned organisational change.

Keywords: staffing arrangements, process operations, risk assessment

OVERVIEW OF ASSESSMENT METHOD

The method concentrates on the staffing requirements for responding to hazardous incidents. Specifically, it is concerned with how staffing arrangements affect the reliability and timeliness of detecting incidents, diagnosing them, and recovering to a safe state.

The method is designed to highlight when too few staff are being used to control a process. It is not designed to calculate a minimum or optimum number of staff. If a site finds that its staffing arrangements 'fail' the assessment, it is not necessarily the case that staff numbers must be increased. Other options may be available, such as improved control, detection, alarm or trip systems.

Assessment is in two parts. The first is a physical assessment of performance in a range of scenarios, the second is a ladder assessment of the management and cultural attributes underlying the control of operations. The overall assessment process is summarised in Figure 1.

The method assesses eleven elements which are comprised of:

- Technical factors: Physical assessment of the feasibility of dealing with each scenario in time.

- Individual factors (workload): Situational awareness; teamworking; alertness and fatigue (split into working pattern and health).
- Individual factors (knowledge and skills): Training and development; roles and responsibilities; willingness to act.
- Organisational factors: Management of operating procedures; management of change; continuous improvement of safety; management of safety.

PHYSICAL ASSESSMENT

The physical assessment tests the staffing arrangements against six 'principles':

1) There should be continuous supervision of the process by skilled operators, i.e. operators should be able gather information and intervene when required. This may take various forms and for example may be satisfactorily provided remote from the primary control area. There is a need throughout the physical assessment to demonstrate that staffing arrangements result in a residual risk which is as low as reasonably practicable.
2) Distractions which could hinder problem detection such as answering phones, talking to people in the control room, administration tasks and nuisance alarms should be minimised.
3) Additional information required for diagnosis and recovery should be accessible, correct and intelligible.
4) Communication links between the control room and field should be reliable. For example, back-up communication hardware that is not vulnerable to common cause failure, should be provided where necessary. Preventative maintenance routines and regular operation of back-up equipment are examples of arrangements to ensure reliability.
5) Staff required to assist in diagnosis and recovery should be available with sufficient time to attend when required.
6) Distractions which could hinder recovery of the plant to a safe state should be avoided and necessary but time consuming tasks, such as summoning emergency services or communicating with site security, should be allocated to non operating staff.

The assessment is in the form of specific questions, each requiring a yes/no answer. The questions are arranged in eight trees. An example tree is shown in Figure 2.

The physical assessment is completed for a range of scenarios. It is necessary to identify scenarios which could result in incidents with major hazard potential. There is no fixed rule on the number of scenarios that should or must be analysed - each plant or unit is different. Selection of scenarios is critical to the quality of the physical assessment and must include the worst case in terms of consequence and operator workload. The site's COMAH report, area HAZOP's or risk assessments plus incident reports can be used in scenario selection and the selected scenarios should be agreed amongst the assessment team prior to the study. It is recommended that scenarios representing the following are analysed:

- Worst case scenarios requiring implementation of the off-site emergency plan;
- Incidents which could escalate without intervention to contain the problem on site;
- Lesser incidents requiring action to prevent the process becoming unsafe.

It may be necessary to assess the scenarios at different times such as during the day and at night, during the week and at weekends, if staffing arrangements vary over these times. The scenario selection process needs to consider these factors when producing a list of representative scenarios as well as the range of inherent hazards and operating areas.

The scenarios must be defined in sufficient detail and historical data relevant to the selected scenarios used in the assessment. Evidence of reliability is required e.g. simulation exercises, equipment reliability data, incident reports.

LADDER ASSESSMENT

The individual and organisational factors are assessed using ladders (see Table 1 - note: the dotted line represents the boundary line between acceptable and unacceptable). There are eleven ladders in total.

Table 1: Example ladder (for training & development)

Grade	Description	Explanation of progression	Rationale supporting assessment
A	**Process/procedure/staffing changes** are **assessed** for **the required changes** to operator **training and development** programmes. **Training** and **assessment** is provided and the **success** of the **change** is **reviewed** after implementation.	The training and development system is dynamic and integrated into the management of change process.	
B	**All operators receive simulator or desktop exercise training** and **assessment** on **major hazard scenarios** on a **regular basis** as part of a **structured** training and development **programme**.	Operators get a regular opportunity to practice major hazard scenarios through physical walk through's or simulators or by desk-top talk throughs.	
C	There is **a minimum requirement** for a **'covering' operator** in a particular role based on **time per month** spent in **the covered role** to ensure **sufficient familiarity**. Their **training and development** programmes **incorporate** this requirement.	It has been recognised that anyone covering roles must be competent and their skills kept up to date in all roles they are expected to cover.	
D	**Each operator** has **a training and development plan** to progress through **structured, assessed skill steps** combining **work experience** and **paper based** learning and training sessions. **Training needs** are **identified** and **reviewed regularly** and **actions** taken to **fulfil needs**.	The training and development needs are identified, provided and reviewed on an individual basis allowing operators to improve and extend their skills and understanding. It provides operators with a motivation to improve and continue to develop.	
W	**All operators** receive refresher training and assessment on **major hazard scenario** procedures on a **regular, formal** basis.	The need for formalised regular refresher training for major hazard scenarios has been recognised as essential when they are such infrequent events with severe consequences.	
X	**New operators** receive **full, formal induction training** followed by **assessment** on the process during **normal operation** and **major hazard** scenarios	Full training and assessment for new operators, it is formalised and covers normal operation plus major hazard scenarios.	
Y	There is an **initial** run through of **major hazard** scenario procedures by **peers**.	Only an informal briefing on major hazard procedures is provided to new operators.	
Z	There is **no evidence** of a **structured** training and development programme for operators. Initial training is **informally** by peers.	Poor practice, staffing arrangements do not fulfil any of the rungs above.	

The assessment team for each ladder element should work through the guidance questions that accompany each ladder and use support material (e.g. procedures, job descriptions, incident reports) as evidence wherever possible.

ASSESSMENT OUTPUT

The method identifies areas of unacceptable risk in process operation staffing arrangements and provides target areas for improvement action. Typical output actions include:

- evaluate costs and benefits of improvement options identified;
- further investigation required, such as determine the reliability of equipment, further analysis of critical tasks, check assumptions about the behaviour of leaks;
- consult with a human factors expert on key judgements.

The output from the method is an action plan for each assessed element. The priority for improvement actions is:

1) Improvement actions required to ensure the reliability of the operations team being physically capable of detecting, diagnosing and recovering from scenarios.
2) Improvement actions required to move the staffing arrangements above the acceptable line on all ladder elements.
3) Improvement actions required to continuously improve the staffing arrangements towards best practice.

PRACTICAL APPLICATION

It is recommended the staffing assessment be managed similarly to other process safety assessments, such as HAZOP or risk assessments supporting a safety case.

It is recommended the assessment of a defined production area be co-ordinated and facilitated by one person who is technically capable and has experience of applying hazard identification and risk assessment methods. The role is similar to that of a HAZOP chairperson.

In addition it is recommended that the assessment team constitute:

- control room and field operators: experienced and inexperienced plus operators from different shift teams;
- operator first line management; if on shift, different shifts should be represented;
- staff who would assist during incidents, perhaps in giving technical advice to operators or with tasks such as answering phones;
- management or administration staff with knowledge of operating procedures, control system configuration, process behaviour, equipment and system reliability, and safety (including risk assessments and criteria).

Teams may require assistance from Human Factors specialists.

WHEN TO APPLY THE METHOD

Good practice is to apply the method in full and to review and reapply the method periodically. The method may be applied to existing arrangements, new arrangements plus changes to existing arrangements.

Changes in staffing arrangements (or other changes affecting the response to emergency or upset conditions) should be evaluated prior to implementation. Any change that could alter the rating from the method is considered to be a change in staffing arrangements. A guiding principle is that changes should not lead to a reduction in the assessment rating.

The procedure for analysing proposed changes is:

- produce an up-to-date baseline assessment of the existing arrangements;
- define the proposed change and evaluate it using the assessment method, modifying the plans until an equal or better rating is achieved;
- re-assess the arrangements at a suitable time after implementation (within six months).

New arrangements can be assessed by defining the roles and responsibilities of operators, line managers and support staff plus their skills and experience in similar detail to that required when assessing a planned change. Training and development programmes, work patterns, safety policy and other issues covered by the assessed elements need to be defined also. As when assessing a change the arrangements should be re-assessed at a suitable time after implementation (within six months).

HAZARDS AND CONTROLS ASSESSED

The selection of hazards and controls examined in the assessment method is informed by Human Factors research into process control operations and sociotechnical systems thinking – i.e. that operator performance is influenced by deeper organisational and management factors. These two perspectives can be seen in the set of ladders, which are split between ladders examining individual factors and ladders for organisational factors. However, in all ladders there is a management theme, emphasising the need to manage hazards.

Staffing has been treated as one of the contingent factors within the context of how organisations are designed for the demands of their operations. Hence it is intended to take account of sociotechnical factors (process hardware, control technology, human and organisational factors) and acknowledge there is no single ‘ideal’ organisational arrangement that must be adopted by all organisations. Therefore the method should

give consideration to how organisations handle the trade-offs between staffing numbers and, for example, interface technologies, automation, communication arrangements, task allocations, team structure etc.

It is also intended the method indicates how 'comfortable' an organisation is in respect of its staffing arrangements : i.e. given its other organisational parameters and the operations it is engaged in, how close to 'unacceptable' is its staffing arrangements.

Human factors research highlights the abilities required of process control staff, and hence the hazards and controls required to:

- be able to take action, reliably and within the necessary time frame;
- be able to follow the condition of the process, anticipate its behaviour and hence select an appropriate control strategy (i.e. have high 'situation awareness');
- be in a fit state to monitor the process (i.e. be awake and attentive);
- be willing to take action as and when necessary;
- be able to take action, reliably and within the necessary time frame;

When working as a team:

- be able to collect and share critical information about the process and control actions, and
- be able to co-ordinate actions.

The physical assessment checks whether the staffing arrangements work in practice. Using the analogy of designing a marketable car, the first test is whether the new design can handle the stresses it will be under. Subjective issues such as whether it is attractive come later. The physical assessment is equivalent to the fundamental check.

THE FORMAT OF THE METHOD

The format of the assessment method is an amalgam of three forms:

- structured hazard assessment methods, such as HAZOP and fault / event tree analysis;
- walk- or talk- through methods;
- anchored rating scales.

These were selected as they are familiar to the chemical sector or are gaining favour. The techniques used in Human Factors research are too demanding in resources or in interpretation skills:

- simulation and real-time observational methods require costly facilities, are time consuming, difficult to interpret and can be disruptive;
- operator self-assessment questionnaires or diaries could be prone to bias due to organisational cultural factors (openness, blame culture etc.) when not used in confidential research. There could be scope for using such methods to tune operators into the issues in the lead up to the analysis using other methods;
- task decomposition methods, including link analysis, face problems in analysing scenarios with uncertainty, into which process upsets and emergency incidents would be grouped

RESULTS OF TRIALS

During development the method was tested in three case studies.

Several areas of unacceptable risk were identified using the method in the case studies and a range of actions for investigation suggested. The need for improvement actions

was identified during the physical assessment and the ladder assessment stages. During the case studies, actions were identified which:

- would lead the staffing arrangements to pass the physical assessment (develop the physical ability to detect, diagnose and recover);
- would lead the staffing arrangements to pass the ladder assessments (produce an acceptable performance on individual and organisational factors);
- would further improve staffing arrangements ability to physically detect, diagnose and recover;
- would further improve the position of the staffing arrangements on the eleven ladders and progress them towards best practice.

Opportunities for improvement were identified in all three case studies which were accepted and welcomed by the sites.

There has been a further 'pilot study' at a site which plans a full study later in 2001. Plus the method has been applied in several full studies using the team assessment approach. At least four of these have assessed planned organisational changes plus several plant and hardware changes with an initial baseline assessment of the current arrangements followed by an assessment of the implications of the planned changes. The output from these full studies is a timetable summarising implementation of improvement actions and changes with appropriate review points.

EXAMPLE OF ASSESSMENT OUTPUT

SITE A

Site introduction

The site has operated since the 1930's although the plant and processes have been changed and upgraded and there have been several changes of ownership. There are several control rooms and operating units on site and approximately 500 people on site in total. Two operating areas were assessed, one comprising a single batch operated unit, the other comprising two continuous process units.

The site had been going through major equipment and organisational changes over the previous 18 months and were part way through these programmes at the time of assessment.

The major hazard for the site is toxic gas release, there are large quantities of two toxic gases on site.

It is surrounded by other major hazard sites and so has to be able to deal with an emergency which is caused by an off site event.

Batch operating area introduction

The control room monitors a batch dilution process. The control has been upgraded within the past 12 months to DCS, there are now level trips on all tanks, there are emergency stops on the plant but there is not one in the control room yet. The E-stop stops the main pump and recirculation pump which maintain flow of the hazardous liquid. Isolation valves have to be operated on the plant, there are no automated isolation valves.

There is one operator on shift to monitor variables in the control room and operate the process on plant. This operator is also responsible for loading tankers a few minutes up the road. He can hear process alarms anywhere on the plant and when loading a tanker. There is a shift supervisor who works from 8am to 4pm. The operations team for this unit are also responsible for the utilities plant which is about 5 minutes away. This unit

has one operator present on shift and the same daytime supervisor is responsible for both units.

There is a team of ten operators who rotate around a five week shift cycle covering the batch chemical stores plant and the utilities plant.

Assessment results

The physical assessment was done for two scenarios within this operating area as part of a limited case study trial of the methodology and the results are summarised in Table 2 (completed trees not included). Both scenarios had occurred on site within the past 2 years, therefore incident reports were available plus the incidents were familiar to the operators interviewed.

Table 2 Summary table for physical assessment of Site A, batch

Scenario #	Scenario Description	Pass	Fail	Physical assessment #('s) failed on	Actions required
1	Flange leak of toxic gas, wind direction towards the road, at night		√	1, 2, 6	Trees 1 & 2: Implement man down alarm which contacts security if two audible alarms are not acknowledged by the operator after 15 seconds and 30 seconds, respectively (identified by area HAZOP). Need to ensure that failure rate of the man down alarm is as low as reasonably practical and of a similar order to safety critical plant items. (Otherwise need to consider other options). Additionally assess benefits of cameras to assist plant monitoring Additionally the benefits of having a mimic of the chemical stores DCS screens in a nearby continuously manned control room could be assessed. Step 6: Implement E-stop in control room (identified by area HAZOP). Additionally, assess benefits of automated isolation valves plus assess benefits of cameras to assist plant monitoring
2	Damage to plastic pipe, toxic chemical dilution by contractor (on days)		√	6	Step 6: Implement E-stop in control room (identified by area HAZOP). Additionally, assess benefits of automated isolation valves plus assess benefits of cameras to assist plant monitoring Plus additional steps to ensure that contractors report incident to security if the operator is not in the control room, by placing a notice in the control room and incorporating as a question in the weekly audits of contractors working on site

Therefore several areas of unacceptable risk were identified from the physical assessment and some suggested improvement actions identified by discussion with the operator and SHE advisor. The problems arise due to the plant having a single operator for control room and plant operations. The suggested improvements above are technology based, an alternative is to make other operator(s) available for plant work. To ensure that an outside plant operator was always available to the chemical stores and that the chemical stores control room was continuously manned, there would need to be a dedicated outside operator to the area which may mean that the utility stores would need a dedicated outside plant operator.

Table 3 summarises Site A's performance on the ladder assessment elements and suggests improvement actions (completed ladders not included). As with the physical assessment, the ladder assessments were done as part of a limited case study trial of the methodology.

Table 3 Summary of ladder assessment for Site A's batch production area

Element	A	B	C	D	E	F	G	V	W	X	Y	Z	Action
Situational awareness													Evidence suggests that it is currently quite difficult for an operator to keep track of process conditions during upset or emergency conditions as they have to personally detect a toxic gas leak as there is only one person who could be in the CR, on plant or loading tankers. The actions suggested in the physical assessment apply to this element
Teamworking													There is a plan in place for the operator to ask for assistance from an operator on the utility plant (if he is available) or to call in the next operator due in. Therefore the exact reasons and scenarios where the operator needs this assistance need identifying and assessing to ensure this arrangement does not introduce unacceptable risk to plant operation
Alertness & fatigue (work pattern)													Although the 'man down' alarm, a suggested action for the physical assessment will alert security if the operator is incapacitated, there is currently no contact between the operator and other personnel on site outside daytime hours. There are several people on site at all times, including a shift supervisor for the main production units. The lone operator is likely to benefit from some interaction with others during a shift to combat fatigue. Assess benefits of introducing interaction with other parts of the site outside normal hours.
Alertness & fatigue (health)													Could introduce review and improvement of health monitoring control
Training & development													New and existing operators would benefit from tabletop exercises on major scenarios. The site would like to do this but have a problem because the current shift system does not allow flexibility for people to be available for training and assessment. A structured training and development plan for each operator is suggested. There are plans for introducing a skill step system as part of a site re-organisation which will incorporate these aspects but this again depends on a change in shift system. Optional shift systems have been assessed but the changes need agreeing with the Unions
Roles & responsibilities													Key requirement is a management control which ensures that core competencies required for the operations team are retained during any staff changes. Plus the need for operator training and development plans are the main actions required to progress up this ladder
Willingness													A peer review of this ladder would be beneficial to ensure all agree about not being fearful of reprimand if they wrongly initiate recovery actions as long as they felt justified in doing so. The progression up this ladder requires the operators being involved in finding ways to reduce the costs of recovery actions which may not be applicable in this operating area as it does not really have costs associated with shutdown.
Management of operating procedures													There are plans in place for the procedures to be audited and for a new management of change system which ensures procedures are kept updated and out of date procedures recalled. It is also planned for the procedure control system to be reviewed and continuously improved. When these are implemented the operating area will progress up this ladder. It may be beneficial to tell people when new operating procedures are put onto the system as the site already does for new quality and SHE documents.
Management of change													The introduction of a review programme for changes would take the operating area up to the top of this ladder

Element	A	B	C	D	E	F	G	V	W	X	Y	Z	Action
Continuous improvement of safety													Key requirement is for the investigations from incidents/events to be used in the review of training needs and operating procedures. This can be done in conjunction with the improvements to the training and development element. This again requires on the operators being available for participation in training activities which the current shift system makes difficult. Additional improvements should be planned after this has been achieved
Management of safety													Operator involvement in continuous improvement teams which tackle quality, environmental and safety issues would progress the operating area up this ladder.

Note

CR = control room

OBSERVATIONS ON HOW THE METHOD COMPARES TO OTHER SAFETY APPRAISAL METHODS

Experience gained during the collaborative case studies suggests the method covers many issues which are not assessed by existing methods such as HAZOP and risk assessment. This particularly applies to the elements covered by the ladder assessments but also to the physical assessment as it is assessing the reality of process operation rather than a frozen P&ID or operating procedure. It also generates greater insights due to operators providing the majority of the assessment input which is often not the case with other methods.

For example an issue arising at one site was:

What would a contractor do if he had caused a toxic gas leak and went to the batch process control room to report it and the control room operator was not present (which is likely as he works alone and can be outside in the plant)?

At the site safety induction contractors are instructed to contact site security on detection of toxic gas. The physical assessment trees identified this as a critical action, since if a contractor tried to locate the operator instead the scenario could develop into an incident with off-site impact. Two contractors were quizzed on what they would do in that particular situation and correctly replied that they would contact security. However to ensure all contractors would act correctly the control room operator and site Health and Safety advisor involved in the assessment identified additional actions such as a reminder notice in the control room plus incorporating the situation as a question to ask contractors on the site weekly audits.

The assessment cross-validated findings from other hazard and risk assessment methods. For example, the physical assessment on a batch chemical dilution plant control room identified areas of unacceptable risk which had been identified during a recent area HAZOP. The problems were associated with lone working and how process alarms or a toxic gas leak would be detected during a night shift if the control room operator (who has no support team) is incapacitated.

One of the sites had recently been audited by a corporate team. This had covered matters including, auditing, emergency planning and response, management of personnel change, incident investigation, contractors, and training and performance. Consequently the audit had looked at some of the topics covered by the staffing assessment method, in particular it had overlapped with some of the ladder elements, but on a site wide basis. It did not overlap with the physical assessment approach. Some of the issues identified by the staffing assessment method had been picked up by the corporate audit, such as training and development. Of course the staffing assessment was focused on part of the site, while the audit was site wide. Nevertheless, the site Health and Safety Advisor commented that in comparison to the audit, the staffing assessment ‘got inside people’s heads’ and both the ladders and physical assessment trees provided discrete measures to gauge themselves and set targets to aim for.

LESSONS AND FUTURE DEVELOPMENTS

LESSONS

From the experience and comments from the piloting case studies and full-scale application, there are grounds for concluding the method fulfils its objectives. Staffing in the process industries is, undoubtedly, a complex issue and determining whether staffing arrangements are safe is a non-trivial task. It is hoped the method allows organisations to make informed decisions about staffing arrangements, particularly when changing staffing arrangements.

Although the method was originally developed to assess staffing arrangements in control rooms, application experience during and since development has demonstrated that generally it is necessary to assess the entire shift operations team and the method easily lends itself to being applied in this way. Plus it may be (and has been) applied where the control room does not perform all detection, diagnosis and response to incidents.

FACILITATOR SKILLS

Although the role of facilitator is akin to the role of HAZOP chairperson, and parallels between the staffing assessment method and the HAZOP technique are apparent, experience to date suggests that there are significant differences between the two roles. People who are skilled in formal process HAZOP may be uncomfortable with steering the staffing assessment process due to the emphasis on Human Factors and management systems. It is recommended when appointing a facilitator that greater weight be given to skills in these areas than to skills in process engineering.

FUTURE USE OF THE ASSESSMENT METHOD

In addition to the tool being used to appraise the management of safety and support safety cases, it provides a ready means of comparing and benchmarking sites. Sharing of the scores poses no commercial risk, and it is unlikely revealing the reasoning behind the ratings will threaten intellectual property or process technology as the method is assessing fundamental human factors and hazard management principles.

One of the functions of the assessment method is to assess the effective implementation of an organisation's safety management system (SMS) in terms of policies, procedures and influence on culture at the operational level and should be used to introduce improvements to an organisation's SMS. It is anticipated that the assessment will sit within the SMS and form an integral part of an organisation's demonstration of safe operation along with technical safety assessments such as HAZOP, reliability assessments etc. The assessment should therefore be treated as a working document which is periodically reviewed to take account of 'drift' in working practices and plant performance. It should be noted that the approach is significantly different to management audits which tend to be very broad, compliance based and not human factors focussed.

FUTURE DEVELOPMENT OF THE ASSESSMENT METHOD

As the method is applied and experience gained it is foreseeable the elements will be reviewed and revised. Some of the elements deal with issues that could be broken down into sub-elements.

The method's framework structure allows it to be added to (new ladders or assessment trees) or modified (e.g. revision of the ladders or use of specialised assessment tools within elements such as task analysis). It is anticipated that expansion or amendment will come as experience of applying the method is accumulated and 'best practice' evolves.

SHOULD THE ASSESSMENT CALCULATE A SINGLE, OVERALL SCORE?

The question of weighting the elements is also a consideration. Among the differences between elements is that they deal with issues that have different time frames and the consequences of 'poor' scores from specific elements are likely to 'decay' the management of safety at different rates. The elements also differ in the degree of 'improvement' they can bring - a strong continuous improvement programme can raise the standard of safety management as a whole. How can weightings be devised to reflect these differences? It is our

perception that the understanding is insufficient to permit valid weights to be assigned. However, as data is gathered, analysis against safety records may reveal correlations.

From a more pragmatic perspective, the pitfalls of an aggregated score resulting in above average controls in some areas masking poor hazard management in others also made us omit an algorithm for combining the scores.

TRANSFER TO OTHER INDUSTRIES

The method has been developed for application in the major hazard process industries to assess the operations teams ability to cope with major incidents. Additionally it can be applied to other processes and medium scale incidents where there may be loss of containment but there is no off-site impact and also to operational problems with financial consequences. Essentially the methodology assesses the effectiveness of a defined group of people who have to respond to stimuli and carry out a defined series of tasks within a specified timescale. The feasibility of the tasks being physically completed is assessed plus the management and organisational controls in place which influence and shape the team's ongoing performance.

Other than the physical assessment trees, which have been formulated to suit the circumstances peculiar to the process industries, it is anticipated the issues addressed in the other elements are generic to many environments. The fundamental check of the physical assessment could be rebuilt from principles relevant to other industries. The ladder elements are applicable to a wide variety of situations although the detailed wording of preparatory questions and ladders may need tailoring for use in other industries.

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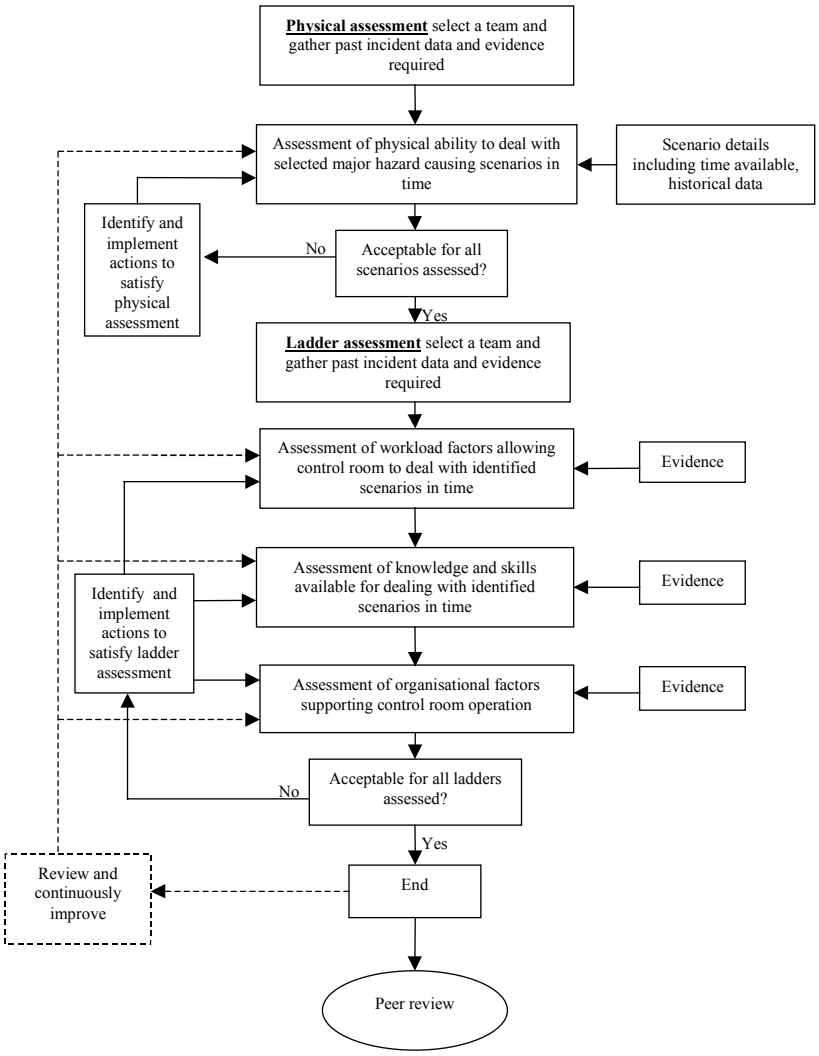

Figure 1: Flowchart of the staffing assessment process

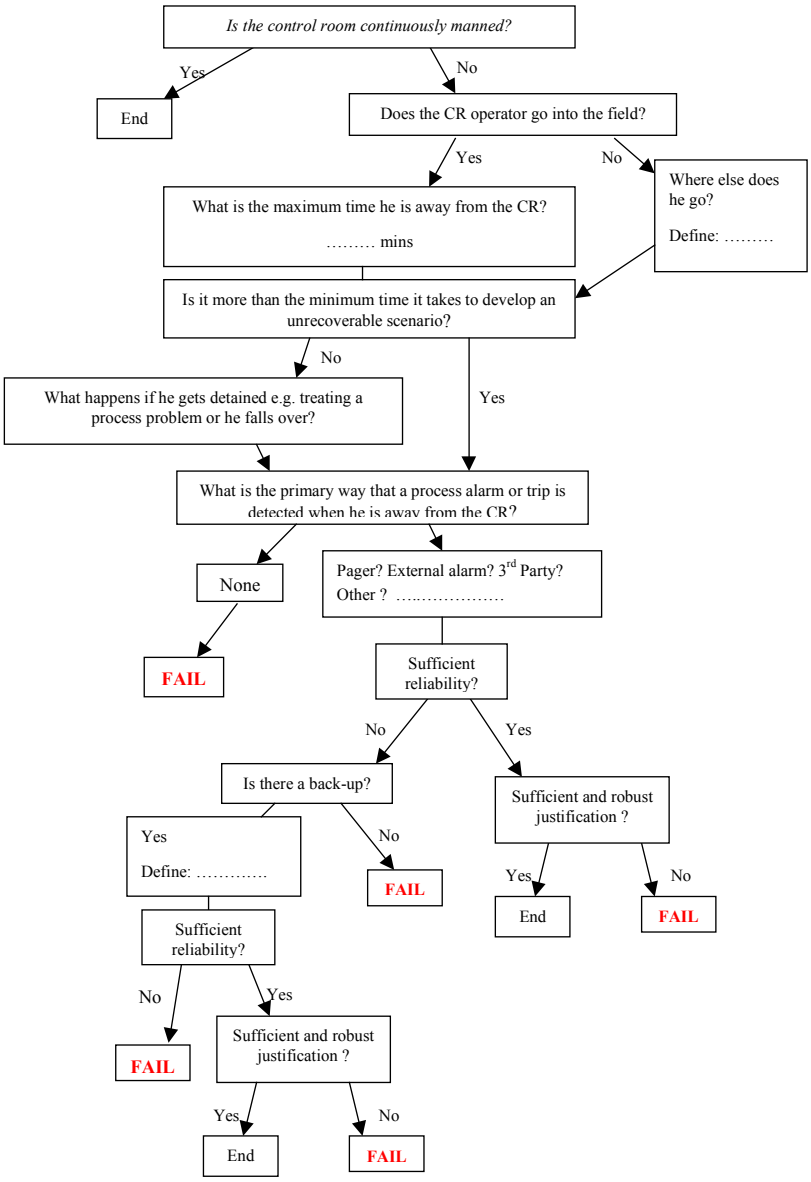

Figure 2: Example tree from physical assessment

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