Practitioner's Section

Engineering an Instrument to Evaluate Safety Critical Manning Arrangements in Chemical Industrial Areas

G.L.L. Reniers*, W. Dullaert*, B.J.M. Ale**, F. Verschueren***, K. Soudan*

* University of Antwerp, Department of Environment, Technology and Technology Management, Antwerp Research Group on Safety and Security (ARGoSS), Prinsstraat 13, P.O. Box B-434, 2000 Antwerp, Belgium
** Technical University Delft, Department of Safety Science, Safety Science Group, P.O. Box 5015, 2600 GA Delft, The Netherlands
*** Belgian Federal Public Service Employment, Labour and Social Dialogue (FOD WASO), Ernest Blerotstraat 1, 1070 Brussels, Belgium
\# Correspondence to: ARGoSS@ua.ac.be

Abstract: Due to the higher workload it produces, reducing the size of operational teams in the chemical process industry can have a negative effect on the ability to control abnormal situations, fatigue, etc. A lack of qualified operational personnel in unusual conditions and the resulting lack of process control can trigger a series of internal or external accidents, eventually leading to a major accident. This paper suggests a practical method to evaluate the safety critical staffing levels required to meet performance specifications for safety critical activities. For single plants as well as for clusters of chemical plants, the method also enables consultants and inspectors to consequently apply principles to assess those manning levels representing the last but one line of defense in the prevention of major accidents.

Introduction

The organizational structure, responsibilities, practices and procedures which comprise a chemical prevention policy are all fixed in the so-called Safety Management System (SMS). One of the key points of such a SMS concerns organization and personnel issues. Guidelines give recommendations to streamline personnel tasks and responsibilities as well as recommendations to establish organizational procedures (such as education and training programmes) with respect to safety.

To date, there have been no directives on safety critical staffing levels. Neither has a best practice been established for the required quantity and/or quality of plant employees needed to monitor certain safety critical tasks which prevent a Loss of Containment (LOC). However, sufficient capable personnel on the job are needed to guarantee safety critical activities to be performed safely. Since there is a large diversity of safety cultures within the chemical process industry, the means of dealing with the Safety Critical Staffing Level issue is highly dependent on individual companies. To the best of the authors' knowledge, a harmonized guideline document for evaluating personnel occupancy in chemical installations does not exist. Nevertheless, evaluating the quality and quantity of operating team staffing levels is a topic of increasing interest to both the Government and industrial area safety management. At present, the matter is subject to discussion and debate among companies as well as between the industry and the authorities. A reason for the growing concern is illustrated in Figure 1.

The index figures make it easy to compare the evolution of productivity and employment over time. Figure 1 illustrates that the Production Index, i.e. a business cycle indicator expressing the volume of output and business activity of the industry, increased by 15 index points over a period of eight years. At the same time, the Employment Index measuring the changes in employment at regular intervals decreased by 9 index points between 1996 and 2004. The steep rise in productivity, combined with the gradual decrease in employment in the chemical industry, could increase the likelihood of having to resort to the last but one line of defense to prevent a LOC, should insufficient staff be allocated to perform safety critical activities. An immediate result would be the increased probability of an accident entailing damage. Making the choice of the required safety critical manning levels in a chemical industrial area more transparent could prove to be a new challenge to safety and risk management. Of course, living with risks remains essentially a management question [2].

To enhance safety by optimizing staffing arrangements within the chemical industry, a safety critical staffing evaluation methodology is needed to offer practical and usable results to inspectors and to plant and cluster management.

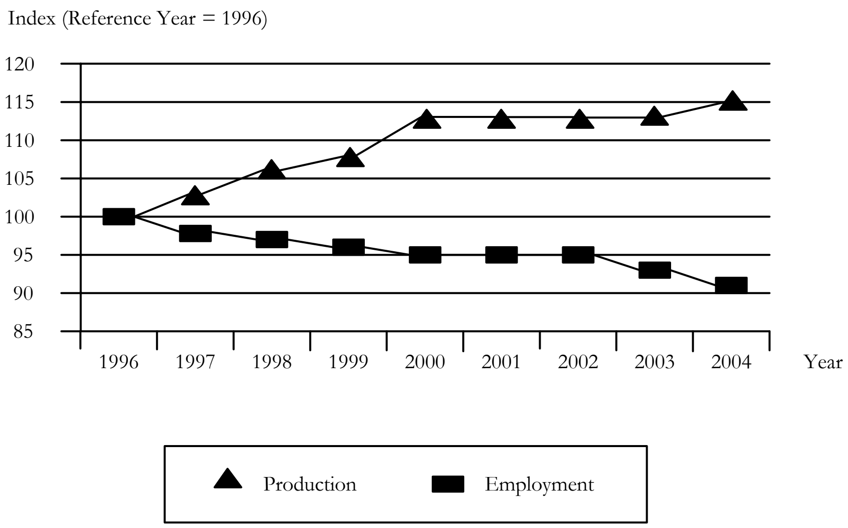

Figure 1: Production index and Employment index in the European chemical Industry (1996 - 2004), Source: based on figures available at [1]

Research objectives

This paper aims at providing support to the chemical industry by objectively evaluating the completeness, the soundness and the quality of safety critical production manning levels with a view to tackling abnormal safety critical circumstances. A real-life example would be the 4-day siege in November 2003 during which the management of a Belgian paint factory were held hostage by unsatisfied employees [3]. Other circumstances (the list is non-exhaustive) which satisfy the term "abnormal" and in which the size of operational teams can be necessarily restricted, are for example a strike (e.g. internal: the next team will not go to work and prevents access to production level, making a shift team change impossible; external: a truck drivers' strike), serious terrorist threat (e.g. hindering or preventing access to an industrial area), a major accident in the neighbourhood of a production installation or at an installation of an adjacent company, a general power supply failure, etc.

Safety managers need guidance on the various requirements for safety critical manning arrangements. A user-friendly document could offer an indication about the issues that have to be improved in terms of staffing levels by suggesting a variety of recommendations depending on the particular problem identified, e.g. improving the safety critical documentation, improving the alarm-management, enhancing communication between different control rooms, increasing the number of manning levels, etc.

Approach

The literature on the subject of staffing levels is limited, indicating that little research has been done in this area. Even in renowned reference works, e.g. "Loss Prevention in the Process Industries" [4], methods, studies, or accident reports investigating the relationship between incidents and staffing levels are not discussed.

The HSE document by Brabazon and Conlin [5] is the most important work on the topic, offering a method for assessing the manning levels in the control room (CR) of one or several chemical installations. The extensive instrument has two parts: a "physical assessment" and a "ladder assessment". The first type uses assessment trees to scan the CR manning levels with respect to six fundamental principles. Organizational factors such as training and development are evaluated with the help of ladder assessments. Using the document, bottle-necks in CR personnel arrangements can be pro-actively detected and handled. Unfortunately, this rather complicated instrument fails to evaluate field operators and its results are not specifically targeted at assessing the staffing levels in safety critical circumstances. Therefore, the document does not meet the final objectives of this examination, i.e., a user-friendly ad-hoc review of all manning levels (including CR operators and field operators) of a cluster/plant to prepare for specific abnormal situations.

Since there is diversity in chemical plant safety cultures, every company has built up its own method to satisfy its specific needs regarding safety and employment. Therefore, it is not likely to use a harmonized instrument with merely quantitative information to compare safety employment structures of different companies. A qualitative procedure [6] allows for the fact that two completely different methods used for addressing a specific manning level problem can be equivalent in their effectiveness.

Empirical results

The study thus far identified theoretical methods to assess staffing arrangements. However, these documents are based on ideas and abstract principles rather than on practical aspects or case studies. In order, therefore, to become acquainted with common practices in the industry as regards manning levels, safety engineers and production managers at 2 multinational chemical companies as well as 2 consultants specialized in determining staffing levels were interviewed. Current practices concerning staffing levels and safety activities were mapped.

Safety activities

The activities designed to ensure safe operations at chemical installations can be divided in terms of the different situations in which they must be executed. A distinction is made between "Standard Safety Activities", "Safety Critical Activities" and "Emergency Activities".

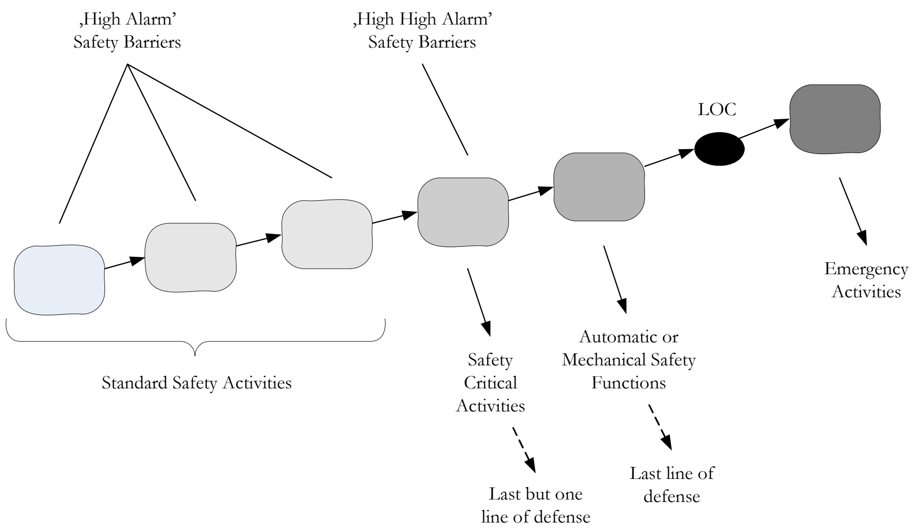

Figure 2: Types of Safety Activities

Standard Safety Activities are activated in the case of so-called "High Alarms". If these interventions are not performed, an unsafe/dangerous situation can occur, possibly leading to the disturbance of process safety, but not yet leading to an accident. The second type of activities, i.e. Safety Critical Activities, is activated in situations characterized in the industry as being "High High Alarms". If the necessary interventions do not take place in such circumstances, this might lead either to an activation of the final line of defense, i.e. an automatic or a mechanical safety function, or directly to a Loss of Containment (LOC). Whatever the case, the probability of a resultant accident with damage substantially increases if no Safety Critical Activities can be supported by the available staff. The final type of activities becomes activated in emergency situations resulting from a LOC. This type is called Emergency Activities and consists of mitigation measures to control the damage. Figure 2 depicts the different types of safety activities. Figure 3 illustrates the different lines of defense in controlling a chemical process.

The last line of defense makes use of Automatic or Mechanical Safety Functions. Automatic Safety Functions act in three stages: first they measure critical chemical process

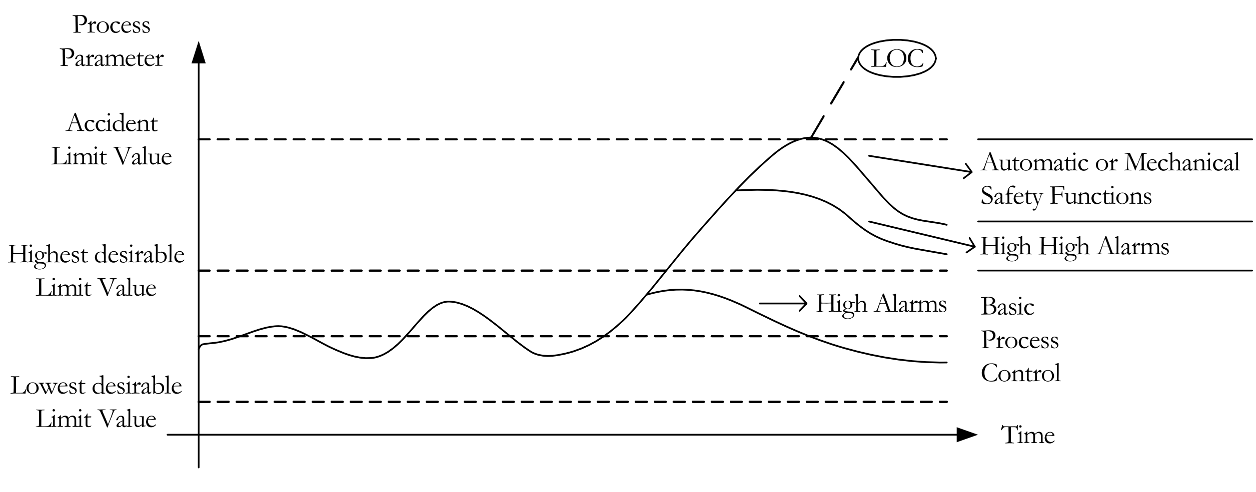

Figure 3: Control and safety of the chemical process, Source: based on [7]

Full Staffing Levels (highest manning)	The number of personnel required (taking task rotation into consideration) in a production team (a production team is composed of field operators, control room operators and all personnel required in the production process of a chemical installation.), accounting for illness, holidays, etc. to guarantee production (safety is guaranteed as well).
Standard Safety Staffing Levels	The minimum number of personnel required in a production team to fulfil all necessary activities (safety critical tasks and standard tasks – *not* emergency tasks). Determined from the productivity viewpoint, i.e. production is guaranteed (safety is guaranteed as well).
Safety Critical Staffing Levels	The minimum number of personnel required in a production team to fulfil all safety critical tasks. If the quality or quantity of personnel falls below this level, personnel substitution must be arranged to prevent having to use the last line of defense or to prevent a LOC.
Minimum Staffing Levels	The minimum number of personnel required in a production team determined from the safety viewpoint, i.e. safety is guaranteed (the last line of defense may be used; production does not need to be guaranteed).
Emergency Staffing Levels (lowest manning)	The minimum number of personnel required in a production team to take care of all emergency tasks.

Table 1: Definitions of staffing levels in decreasing order of manning

parameters, second they decide upon the need for action and finally they work automatically if required. These functions require electricity to be activated. Mechanical Safety Functions (e.g. a safety valve) are self-sustainable and do not require electricity for their performance. An extreme deviating process condi-tion suffices to activate these functions.

To minimize the probability of having to use the last line of defense when handling chemical installations is essential for obtaining sustainable safety. The safety dependency on the last line of defense goes hand in hand with the following drawbacks. On the one hand, Automatic Safety Functions require electricity for solid and reliable functioning and thus installation safety depends on electricity availability. On the other hand, mechanical safety functions can in fact be seen as controllers of small Loss Of Containments preventing a large LOC.

Staffing levels

Table 1 offers an overview of definitions of the different possible types of manning levels in the industry, ranking them in decreasing order. An attempt is made to position the Safety Critical Staffing Levels on this scale.

To determine minimum staffing arrangements for process operations, two main types of methods are used in the industry. One option is to determine staffing levels aimed at guaranteeing production at all times. This leads to the implementation of Standard Safety Staffing Levels. Another option is to establish staffing levels in accordance with safety considerations, resulting in Minimum Staffing Levels. The latter choice obviously requires less manning than the first option.

Methods used by consultants to minimize staffing levels in the CPI emanate from considering worst-case scenarios, e.g. the shutdown of chemical installations as a result of an electrical power supply failure. In case tasks which have to be fulfilled are listed, providing insights into the need of all sorts of functions and their numbers under these abnormal conditions in order to guar-antee the performance of Safety Critical Activities. To further optimize staffing levels, the sequence of activities can be examined to evaluate the necessity of parallel execution. If activities can be performed in a serial manner, manning can be reduced even further. Although at first sight appealing, this approach has some disadvantages. Under abnormal circumstances, operators are already under a great deal of pressure increasing even more the likelihood of them committing errors. Furthermore, cutting the manning levels leads to a lack of back-up operators, which can be of crucial importance should there be a situation in which abnormal circumstances combine (e.g. when a domino accident occurs).

To determine Safety Critical Staffing Levels and thus optimize the last but one line of defense to prevent major accidents at a chemical installation, a trade-off between the activities ensured by Minimum Staffing Levels and those ensured by Standard Safety Staffing Levels should be made by industrial area management. On the one hand, production does not have to be guaranteed under every circumstance if activities ensuring the prevention of major accidents are not affected, which implies that Standard Safety Staffing Levels can be regarded as the maximum of the "safety critical manning". On the other hand, safety has to be guaranteed under every circumstance with a certain degree of back-up, suggesting that Minimum Staffing Levels should be taken as a minimum for "safety critical staffing". Therefore, the optimal Safety Critical Staffing Levels are situated in between the two types of staffing levels currently used in industrial practice.

Methodology

The principles

Reniers et al. [8] point out that the use of checklist analysis is very widespread and well-known in the chemical process industry. Moreover, checklist reviews are very user-friendly and can be applied to diverse subjects [9, 10]. Therefore, an evaluation instrument is elaborated in the form of a checklist to consider safety critical tasks in the control room as well as in the field. Each company has its own trade-offs between the number of personnel and the technology present, automatisation, communication structures, team structure, etc. Given that there is thus no generally accepted definition of a "best safety manning level" regarded as valid for all industrial areas, technological, human and organizational factors have to be kept in mind while making a staffing level assessment. Therefore, the method is developed to cope with different possible physical configurations within the staffing level arrangements in an industrial area. The possible configurations are:

- One or more operators with all-round competence are responsible for the activities in the control room and in the field;
- One or more CR operators who permanently staff the control room and one or more field operators working only in the field. Eventually, within both groups, competences can be arranged in such a way that operators are interchangeable;
- Field operators who are not permanently present, but who may be summoned from elsewhere within the plant/cluster to assist one or more permanent CR operators under safety critical situations;
- Control room operators and field operators not constantly present, but who may be summoned from elsewhere within the plant/cluster to ensure a safe situation under safety critical circumstances.

Safety Problem Parameter	Principle	Interpretation
Safety Problem Detection	**1. Supervision/ intervention possibility**	There should be continuous supervision of the process by skilled field- and CR operators and the possibility to intervene whenever needed.
	2. Distractions	Distractions such as answering the phone, talking to people, performing administrative tasks and acting upon nuisance alarms should be minimized to reduce the possibility of missing/overseeing/responding too late to alarms.
Safety Problem Diagnosis	**3. Information**	Sufficient information required for diagnosis and recovery should be easily accessible, correct and intelligible.
	4. Communication links	Communication links at single plant level as well as at cluster level between the control room and the field as well as between different control rooms should be reliable.
Safety Problem Recovery	**5. Assisting personnel**	Staff required for assisting in diagnosis and recovery should be available in time and with sufficient time to attend when required.
	6. Recovery operations	Operating staff should be allowed to concentrate on recovering the plant to a safe state. Necessary but time-consuming activities should therefore be allocated to others, e.g. summoning emergency services or communicating with adjacent plant safety management. Moreover, all recovery operations should be executed in time.

Table 2: Parameters and principles to deal with occurring problems, Source: based on [5]

During the staffing level arrangement assessment, the safety and the lay-out of the industrial area is subject to evaluation. The lay-out of the company/cluster and of the control room is investigated in terms of whether operators are able to move from one point to another within certain time limits, the consequences resulting when operators are not able to be in a particular place within a given time are identified and the reliability of the supporting equipment and the supporting documentation is questioned.

In summary, the evaluation verifies whether Safety Critical Staffing Levels in an industrial area affect the reliability and timeliness of detecting safety critical problems, diagnosing them, and lifting recovery to a safe state. Therefore, conditions such as the number of people required, the means necessary and the competences needed to be able to guarantee safety in the case of calamity is checked against six principles (see Table 2).

The instrument is conceived to identify the possible bottle-necks of personnel organization and to find a solution for a problem under abnormal circumstances. To do this, four questions for every principle are addressed:

- Can the principle be violated?
- In what way has the principle been/could the principle be violated?
- What are the measures to counter the violation?
- Are these measures reliable and effective?

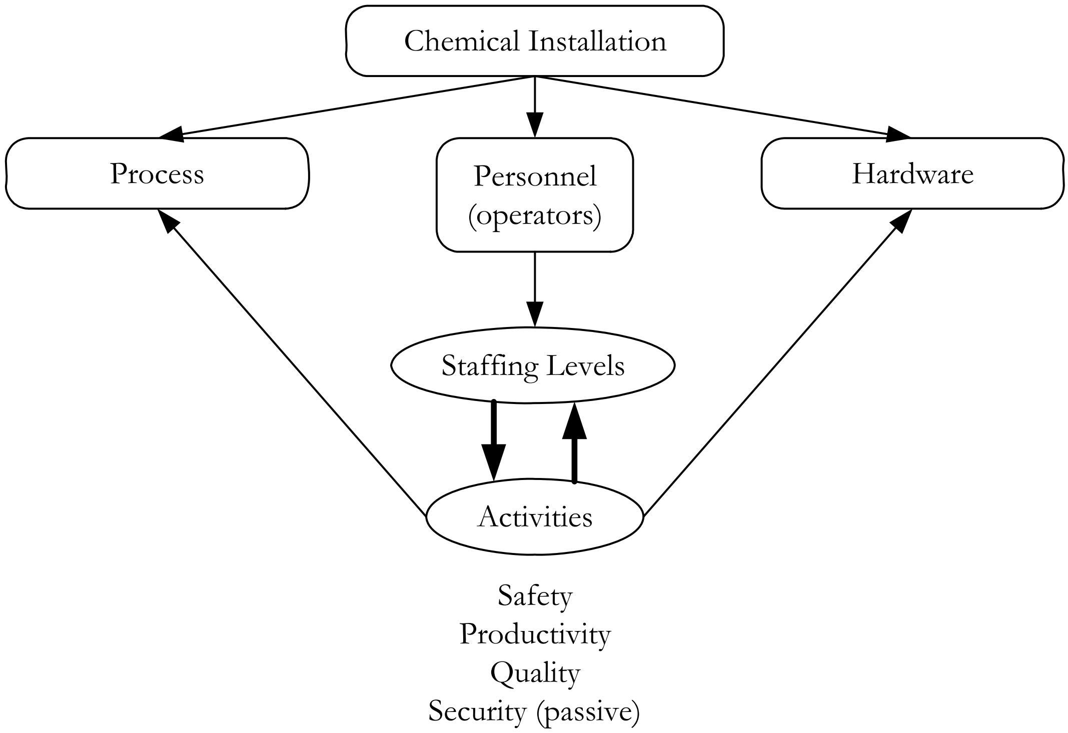

Figure 4: A chemical installation and its operational requirements

Failing on one of the above questions indicates a gap in the industrial area's personnel organization and implies that actions are required to deal with this failure. Because each "failure" is different a gradation is added to the different assessments, e.g. A is considered "best practice", D "worst practice". If an industrial area fails to be situated in the A or B category, the staffing level safety in the area is insufficient and some measures are needed. Directives for such measures are given in the evaluation instrument itself. For example, to be able to improve from category C to category B, a back-up alarm warning system might be installed.

It is also important first of all to check whether operators have the knowledge and the skills to perform their tasks as required and secondly to check whether the safety policy within the company/cluster meets all the requirements.

Personnel to be interviewed

Generally speaking, it is not possible to interview every person who might be involved in a possible sudden abnormal situation concerning safety staffing levels. Nevertheless, it is important to interview as many different people as possible concerned in practice with the problem(s) at hand. Whatever the circumstances, safety management, production management and supervisors are interviewed. If possible, other stakeholders to be interviewed include:

- CR operators and field operators. The recommendation is to interview experienced and inexperienced operators as well as operators belonging to different shift teams;
- Assisting personnel offering support during safety critical circumstances, e.g. by giving technical advice or answering telephones;
- Management and administrative personnel with knowledge of operational procedures and reliability of materials and systems.

To enhance the objectivity of staffing level evaluation, certain documents are required to verify the answers when filling in the checklist. When evaluating an answer from the questionnaire, the final judgement depends on the evidence given by the people answering the checklist. If the answers accompanied by the necessary documents are considered insufficient to underwrite staffing level safety on a specific topic, the area fails for this topic. Extra documents which might be needed include estimation calculations or experiments (simulations) regarding the amount of time needed to react to incidents, data of previous accidents and/or observations of exercises, reliability studies of critical equipment, etc.

Safety critical activities

To determine Safety Critical Staffing Levels, the relationship needs to be identified between the activities to be executed in abnormal circumstances and the corresponding staffing levels. Figure 4 presents an overview of operating a chemical installation.

The reciprocal relationship between activities performed on an installation and the different possible staffing levels of the same installation needs to be investigated to guarantee that Safety Critical Activities can be performed in unusual circumstances. Figure 5 illustrates the different paths leading to an accident if the last but one line of defense fails and offers suggestions to determine the activities that have to be taken into account in the checklist.

In Figure 6, a decision chart is given to distinguish between activities which select the activities to be catalogued as "Safety Critical Activities" in the evaluation.

The tasks emerging from Figure 6 are those which define the Safety Critical Staffing Levels in this research. Once the Safety Critical Activities are identified, the evaluation document as developed in the next section can be used.

The safety critical staffing evaluation instrument

The instrument, which amounts to a checklist, puts forward a number of binary (yes/no) questions related to the six principles of Table 2. All questions lead to an indirect evaluation of the possibility of performing the Safety Critical Activities (listed as a result of executing the Figure 6 decision chart) in an industrial area. The checklist answers should provide a clear insight into the ability of an industrial area to handle safety critical problems in the field and in the control room(s). To verify whether the interviewees interpret the questions in the right

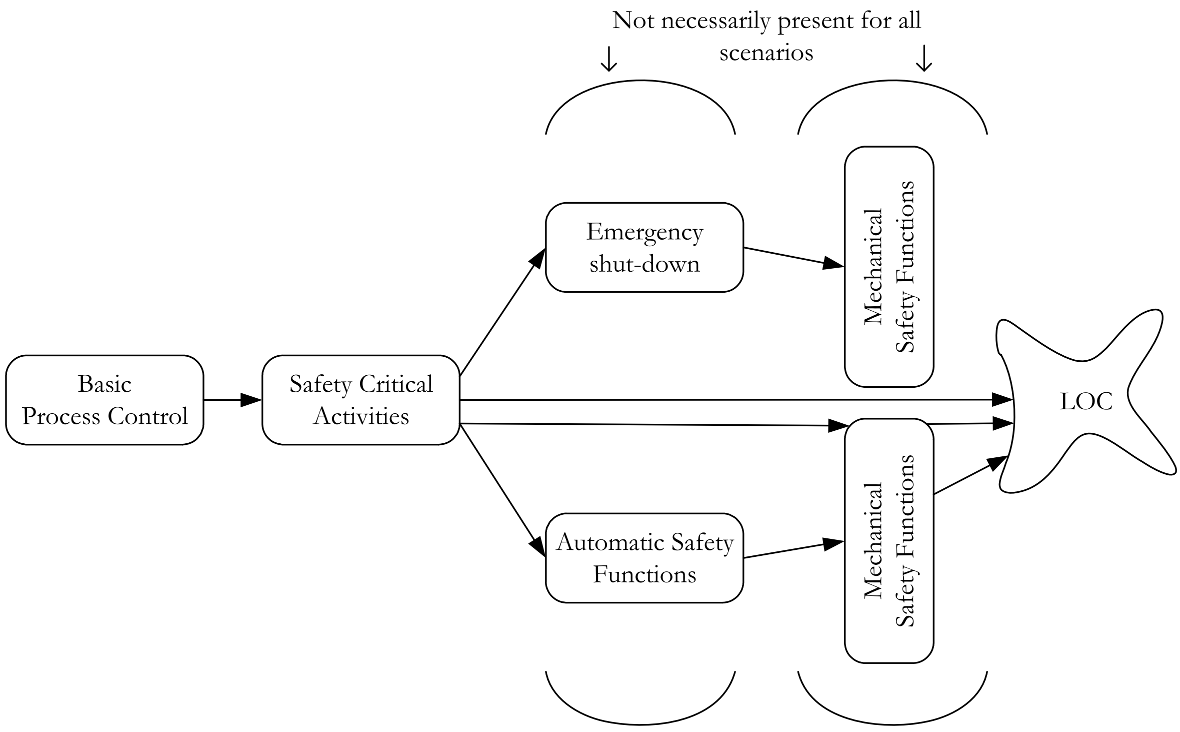

Figure 5: From Basic Process Control to Loss of Containment

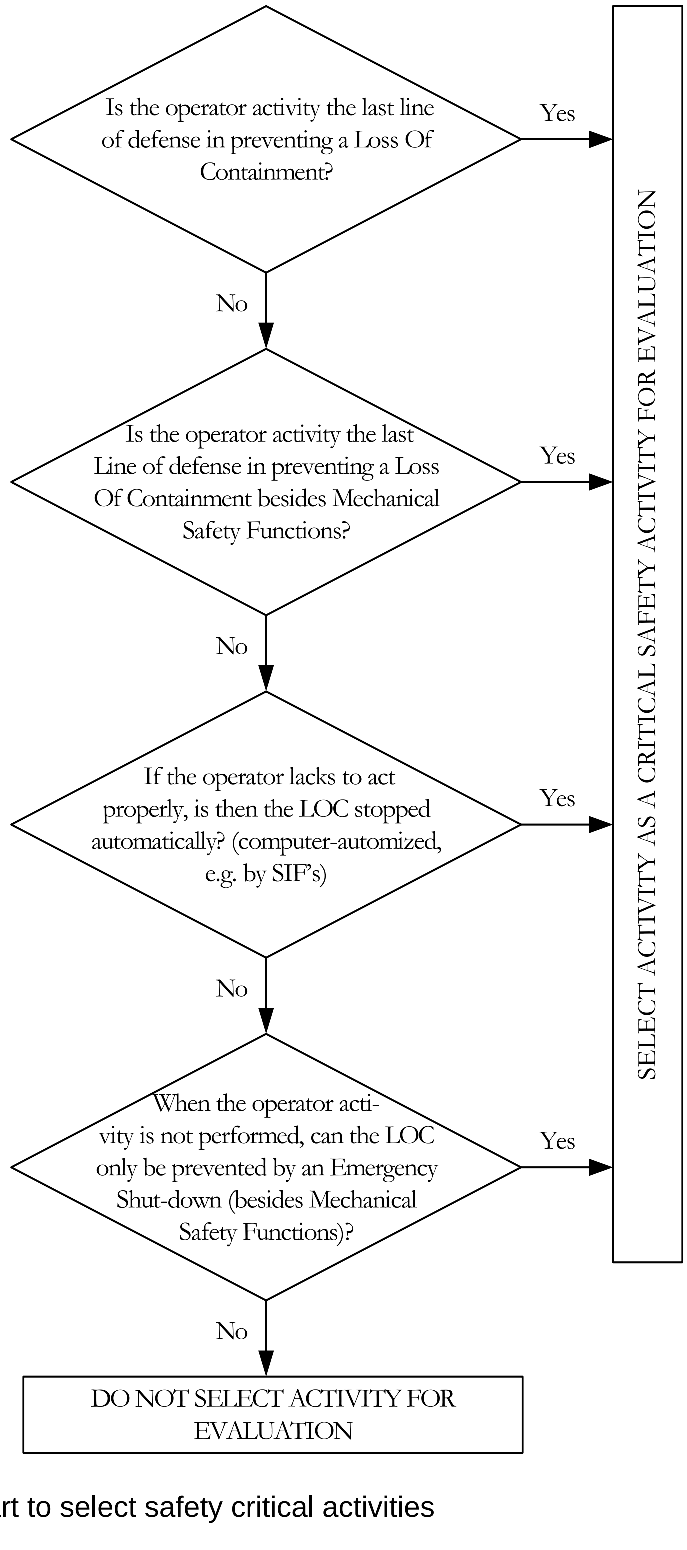

Figure 6: Decision chart to select safety critical activities

way, a control question (indicated "C.Q.") is inserted for each yes/no question. This C.Q. is an open question asking for evidence, information and documentation to support the "yes" or "no" rating on the binary question. The complete instrument is shown in the appendix.

Evaluating the checklist results

As indicated before, three parameters are important for monitoring process installation safety, i.e. detection, diagnosis and recovery of problems.

Problem Parameter	Ranking	A	B	C	D	Total Ranking
Detection	**Principle 1**	1A	1B	1C	1D	
	Principle 2	2A	2B	2C	2D	
Diagnosis	**Principle 3**	3A	3B	3C	3D	
	Principle 4	4A	4B	4C	4D	
Recovery	**Principle 5**	5A	5B	5C	5D	
	Principle 6	6A	6B	6C	6D	

Table 3: Safety critical staffing evaluation tabulation to be filled in

Degree	Description
A	The parameter of the safety critical problems is **guaranteed** by the **inherent** presence of a sufficient quality and quantity of **staffing level.** The organization of the industrial area personnel guarantees safety in safety critical circumstances.
B	The parameter of the problem is **guaranteed**. There is no need for any kind of back-up system to solve the safety critical problem. However, there is one disadvantage: the quality and/or the quantity of the staffing level is not sufficient to guarantee the inherent presence of competent personnel, information and/or communication in the case of safety critical circumstances. The **problem can be tackled promptly addressing the qualitative and/or quantitative staffing level required**.
C	The quality and/or the quantity of the staffing level **suffice** to solve safety critical situations thanks to the presence of **back-up systems**. To be able to cover highly unlikely circumstances, actions should be taken. **Measures are needed** to ameliorate the response rate with which the staffing level is recovered and/or to ameliorate the quality and/or the quantity of the staffing level.
D	The **organisation of personnel fails.** For this problem parameter, the staffing level should ameliorate in a qualitative and/or quantitative manner. The industrial area is not capable of guaranteeing safety and preventing incidents in the case of abnormal circumstances.

Table 4: Description of the different gradings for the safety critical staffing evaluation instrument

For each of these three issues, two principles are checked. The evaluation of every principle, and hence every question, leads to a safety critical staffing ranking ranging from "A" to "D". Table 3 offers an easy-to-use ranking tabulation, indicating the company Safety Critical Staffing Levels' failures.

In the "Total Ranking" boxes, the worst of the combined ranking outcomes is always assigned for each problem parameter. For example, if ranking principle 1 = 1A, and ranking principle 2 = 2C, then the total ranking for detection of problems would be "C". The implications of the ranking degrees A, B, C or D in terms of the final decision are given in Table 4.

Conclusions

An effective industrial area Safety Management System is characterized by the solid evaluation of its constituents. A very important topic for managing safety in process installations is the quality and the quantity of staffing levels required to perform safety critical activities. These activities represent the last but one line of defense for preventing accidents. This paper provides a user-friendly checklist for evaluating the manning levels

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in an industrial area to meet the needs of plant or cluster safety management as well as of government safety inspectors. The information required for using the checklist can vary considerably from cluster to cluster and facility to facility. Therefore, the checklist provides guidelines for collecting the right information to support the evaluation of the current staffing levels.

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Appendix

1. Supervision / Intervention possibility (Detection)	**Yes**	**No**
1.1. Is continuous supervision possible (24/7)		
A. in the Field (manual interventions)?	□	□
B. in the Control Room (computer operated interventions)?	□	□
C.Q.: In which way can this be guaranteed (qualitatively as well as quantitatively)? e.g. - one all-round competent operator is assigned to the Control Room and to every part of the process installation; - one operator assigned to the Control Room supported by several Field operators are responsible for certain parts of the process installation; - several operators are responsible for the Control Room and for some parts of the process installation (having an all-round competence).		
If both answers are rated "yes", ranking 1. =1A, go to 2.1; otherwise go to 1.2.		
1.2. Does a discernable and audible alarm exist which is sent to a location (e.g. central CR of plant/cluster) where personnel is permanently (24/7) located should a safety critical problem arise?		
A. in the Field (manual interventions)?	□	□
B. in the Control Room (computer operated interventions)?	□	□
C.Q.: Does the possibility exist the alarm might fail?		
If both answers are rated "yes", ranking 1. =1B, go to 2.1; otherwise go to 1.3.		
1.3. Does a back-up system exist to report a safety critical problem		
A. in the Field (manual interventions)?	□	□
B. in the Control Room (computer operated interventions)?	□	□
C.Q.: Does the possibility exist the system might fail?		
If both answers are rated "yes": ranking 1. =1C; otherwise ranking 1. =1D; go to 2.1.		
Extra documents to consult in order to evaluate principle 1: shift team system, operator competence schemes, workschemes, technical information concerning the alarm, technical information concerning the back-up system, etc.		

2. Distractions (Detection)	**Yes**	**No**
2.1. Do the operators have to perform/attend to other specific tasks (e.g. answering phones, administration, production tasks, etc.) in addition to Safety Critical Activities		
A. in the Field (manual interventions)?	□	□
B. in the Control Room (computer related interventions)?	□	□
C.Q.: If the answer is 'no', how can this be guaranteed?		
If both answers are rated "no", ranking 2. =2A, go to 3.1; otherwise go to 2.2.		
2.2. Does an alternative exist in case the operators miss an alarm due to other tasks		
A. in the Field (manual interventions)?	□	□
B. in the Control Room (computer related interventions)?	□	□
C.Q.: What is the alternative? (e.g. the alarm is sent to a third party, there is a continuous alarm on the same level, there is a new alarm at the next warning level, etc.)		
If both answers are rated "yes", go to 2.3; otherwise ranking 2. =2D, go to 3.1.		
2.3. Is the time left sufficient to respond to the alarm?		
A. in the Field (manual interventions)?	□	□
B. in the Control Room (computer related interventions)?	□	□
C.Q.: On which basis is the time margin defined in the industrial area?		
If both answers are rated "yes": ranking 2. =2B if time margin exceeds 5min.; ranking 2. =2C if time margin < 5min.; otherwise ranking 2. =2D; go to 3.1.		
Extra documents to consult in order to evaluate principle 2: listing of (other) operator tasks, technical information concerning the alternative alarm, technical information concerning the time definitions within the company, etc.		

3. Information (Diagnosis)	Yes	No
3.1. Is it necessary to consult extra information in order to diagnose and solve a possible safety critical problem		
A. in the Field (manual interventions)?	□	□
B. in the Control Room (computer related interventions)?	□	□
C.Q.: If the answer is 'no', how will the problem be diagnosed and solved? ***If both answers are rated "no", ranking 3. =3A, go to 4.1; otherwise go to 3.2.***		
3.2. Is it possible to attain this information 24/7		
A. in the Field (manual interventions)?	□	□
B. in the Control Room (computer related interventions)?	□	□
C.Q.: How can the attainability of the information be guaranteed? ***Go to 3.3.***		
3.3. Is this information (concerning every topic) always correct and intelligible?		
A. in the Field (manual interventions)?	□	□
B. in the Control Room (computer related interventions)?	□	□
C.Q.: How can this be guaranteed? ***If both questions 3.2 and 3.3 are rated "yes" for all topics, ranking 3. =3B, go to 4.1; otherwise go to 3.4.***		
3.4. Does a back-up system exist to provide information in the industrial area		
A. in the Field (manual interventions)?	□	□
B. in the Control Room (computer related interventions)?	□	□
C.Q.: Explain the back-up system. ***If both answers are rated "yes", ranking 3. =3C, go to 4.1; otherwise go to 3.5.***		
3.5. Does another possibility exist in which the problem can be diagnosed and solved		
A. in the Field (manual interventions)?	□	□
B. in the Control Room (computer related interventions)?	□	□
C.Q.: Explain the alternative solution. (e.g. cluster know-how with extra information) ***If both answers are rated "yes", ranking 3. =3C; otherwise ranking 3. =3D, go to 4.1.***		
Extra documents to consult in order to evaluate principle 3: listing of safety critical problems, technique of attainability, technical information about the system which provides back-up information, technical information concerning the alternative solution, etc.		

4. Communication links (Diagnosis)	Yes	No
4.1. To diagnose and to solve certain safety critical problems, is there some kind of communication link required A. between the Field operators?.......... B. between the Field operator(s) and the Control Room operator(s)?.......... ***C.Q.:*** If the answer is 'no', how can this be guaranteed? ***If both answers are rated "no", ranking 4. =4A, go to 5.1; otherwise go to 4.2.***	☐ ☐	☐ ☐
4.2. Can this communication link be guaranteed 24/7? A. between the Field operators?.......... B. between the Field operator(s) and the Control Room operator(s)?.......... ***C.Q.:*** How can it be guaranteed? ***If both answers are rated "yes", ranking 4. =4B, go to 5.1; otherwise go to 4.3.***	☐ ☐	☐ ☐
4.3. Does a back-up system exist concerning one or more communication links within the plant/cluster which can be guaranteed 24/7 for usage in abnormal situations (NOT emergency situations!).......... ***C.Q.:*** Explain the back-up system. ***If the answer is rated "yes", ranking 4. =4C, otherwise ranking 4. =4D, go to 5.1.***	☐	☐
Extra documents to consult in order to evaluate principle 4: listing of communication links, technical specifications concerning the communication links and their assurance, technical information concerning the back-up system, etc.		

5. Assisting personnel (Recovery)	Yes	No
5.1. To recover certain safety critical problems, is manning assistance needed A. in the Field (manual interventions)? .... B. in the Control Room (computer related interventions)? .... ***C.Q.:*** If the answer is 'no', how can this be guaranteed? ***If both answers are rated "no", ranking 5. =5A, go to 6.1; otherwise go to 5.2.***	☐ ☐	☐ ☐
5.2. Is this manning assistance available 24/7 A. in the Field (manual interventions)? .... B. in the Control Room (computer related interventions)? .... ***C.Q.:*** How can this be guaranteed? ***Go to 5.3.***	☐ ☐	☐ ☐
5.3. Can this manning assistance arrive in time A. in the Field (manual interventions)? .... B. in the Control Room (computer related interventions)? .... ***C.Q.:*** How is this time margin defined? Explain. ***If both questions 5.2 and 5.3 are rated "yes" for all topics, go to 5.4; otherwise ranking 5. =5D, go to 6.1.***	☐ ☐	☐ ☐
5.4. Does a back-up system exist if the call-up system for summoning the manning assistance fails A. in the Field (manual interventions)? .... B. in the Control Room (computer related interventions)? .... ***C.Q.:*** Explain this back-up system. ***If the answers to questions 5.2, 5.3 and 5.4 are all rated "yes": ranking 5. =5B if time in which availability is ensured is less than 5min.; ranking 5. =5C if time in which availability is ensured exceeds 5min.; otherwise ranking 5. =5D; go to 6.1.***	☐ ☐	☐ ☐
Extra documents to consult in order to evaluate principle 5: shift team system, manning assistance system, technical information about attainability of manning assistance, time margin calculations, back-up system information, etc.		

6. Recovery operations (Recovery)	Yes	No
6.1. Can recovery operations be accomplished within the minimum calculated time margin A. in the Field (manual interventions)?	☐	☐
B. in the Control Room (computer related interventions)?	☐	☐
C.Q.: How can this be guaranteed? (e.g. task analyses, desktop exercices, simulations, etc.) ***If both answers are rated "yes", go to 6.2.; otherwise go to 6.5.***		
6.2. Is it possible that the operators A. are assigned extra recovery operations (e.g.: back-up activities of other operators within the plant/cluster)? ……………………………………………………………………………..…...	☐	☐
B. are assigned extra tasks (e.g.: responsibility for site alarm, emergency phone services, responsibility for non-critical alarms? ………..……………………………………………………..…	☐	☐
C.Q.: If the answer is 'no', how can this be guaranteed? ***If both answers are rated "no", ranking 6. =6A, stop audit; otherwise go to 6.3.***		
6.3. Are they timely informed about the extra assignments?	☐	☐
C.Q.: How can this be guaranteed? ***If the answer is rated "yes", go to 6.4; otherwise ranking 6. =6D, stop audit.***		
6.4. Can all assigned tasks be accomplished (originally assigned recovery operations, extra assigned recovery operations and extra tasks) A. by Field operators?..	☐	☐
B. by Control Room operators?..	☐	☐
C.Q.: How can this be guaranteed? ***If both answers are rated "yes", ranking 6. =6B, stop audit; otherwise go to 6.5.***		
6.5. Does a back-up solution (at plant/cluster level) exist should it prove impossible to accomplish the tasks A. for Field operators?...	☐	☐
B. for Control Room operators?...	☐	☐
C.Q.: Explain the back-up system. (e.g. extra back-up operator, assistance personnel to handle the administrative tasks and technical support) ***If both answers are rated "yes", ranking 6. =6C; otherwise ranking 6. =6D; stop audit.***		
Extra documents to consult in order to evaluate principle 6: recovery time margin calculations/simulations, technical recovery information/data, back-up system data, etc.		

Appendix 1: Instrument for evaluating safety critical staffing levels

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