THE HAZOP RISK MANAGEMENT TECHNIQUE

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Introduction

This article is intended to provide a clear explanation of Hazard and Operability Studies, and demonstrate how HAZOPs are applied in practice. Furthermore this article will provide examples of how industries have adopted this method, how it has been adapted to suit various circumstances and how it has been integrated with other techniques. In addition, an analysis of HAZOPs will also be provided, where the advantages and disadvantages of the technique will be presented.

Background of Hazard & Operability Studies

The origins of HAZOPs can be traced historically to Imperial Chemical Industries (ICI). The creation of the HAZOP was ultimately due to the advance in technology, new plant, and the increasing complexity of processes. ICI created a technique that could systematically identify hazards within an operational context. Previous checklists and codes of practice were used to identify potential risks, but could only review past events, and were not applicable to new plant and processes. Because of their tendency to overlook significant issues required in the design phase of the plant or process, HAZOPS were created to be applied in chemical and petrochemical industries. The use of HAZOPs became fashionable after the Flixborough Disaster in 1974, which killed 28 people.

Definition and Basic Concept of Hazard & Operability Studies

HAZOP is a qualitative method of risk analysis and is essentially the systematic study of an existing or planned process, with the purpose of identifying possible problems that could present a risk for the user or which prevent the proper operation for which a process or plant was designed. The main objective of a HAZOP study is to determine the intention of the plant or process, any deviation that can occur from their original design intent, the causes of the devia-

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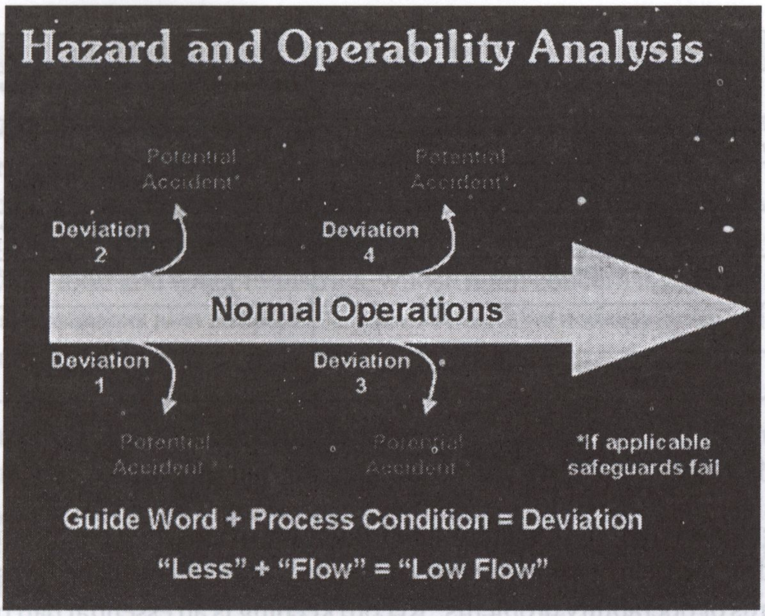
This article is dedicated to the memory of Kewal Salhotrha.

tion, and consequences of the deviations. A HAZOP fundamentally breaks down a complex system or process, then systematically examines individual components of the process, and then forecasts how deviations can emanate from their original design intent. A HAZOP is valuable when analysing complex systems or processes, as the system being analysed is sub-divided into manageable units, then examined in depth as opposed to analysing the process in its entirety. HAZOPs can be carried out prior, during, or even after the design process, however it is recommended that the HAZOP be applied during the design phase, as this limits and minimizes problems of post-design implementation. The HAZOP is normally carried out by a team of between 3 to 9 individuals. A team leader is selected, whose responsibility will be to select the remainder of the team, chair meetings, and plan and prepare the study. The team usually consists of process engineers, safety personnel, operations personnel and a number of other relevant specialists. HAZOPs are best carried out as a team approach, as processes and plant may be technical and complex, and various experts / specialists may be required, possibly after the team has been formed. The members of the team will all normally have their own area of speciality that they can apply to the study. The team will also vary in direct correlation to complexity of the study. Moreover when trying to establish any possible deviations it is important to have varying perspectives, and there is greater potential in a team identifying risks or potential hazards as opposed to an individual. The HAZOP process is centred on the use of guide words. The guide words allow the HAZOP team to identify possible causes for deviations in the process or plant (refer to Figure 1.1). Information obtained whilst conducting a HAZOP is used to ensure that safeguards are put in place to prevent deviations re-occurring and therefore to avoid future failures.

Figure 1.1: Hazard and Operability Analysis Diagram



Source: (United States Coast Guard, 2006, p1

Figure1.1 indicates how normal operations can deviate, and that they can potentially lead to the occurrence of an accident. It also that in order to identify the deviation the Hazop team will apply guide words to determine the cause of the deviation.

Guide Words

In order to conduct the study the team will apply guide words, which can be primary or secondary. The primary guide words will directly relate to the operational aspect and design intent of the plant or process being studied. Examples of primary key words in relation to the hazards are: flow, pressure, temperature, corrode, and erode.

In addition there may also be a number of primary guide words in relation to operability such as: start up, drain, isolate, and vent. As mentioned above secondary key or guide words are also used. When primary and secondary key words are used in conjunction, they suggest potential problems or deviations that can occur. Some examples of key words are as follows; reverse, no, less, early, late, and fluctuation. Figure 1.1 indicates that the combination of the guide word and process condition will result in the deviation, and this is similar to the circumstances when the primary guide word and secondary guide word are placed together in order to determine the possible deviation. Figure 2.0 provides a greater appreciation of the secondary key words, and also provides clear examples of their use. Refer to Figure 2.1 for an example of a flow chart which represents a HAZOP process. (Also refer to Appendix B.)

Figure 2.0 Secondary Keyword Guide (Source: Rausand, 2005, p28)

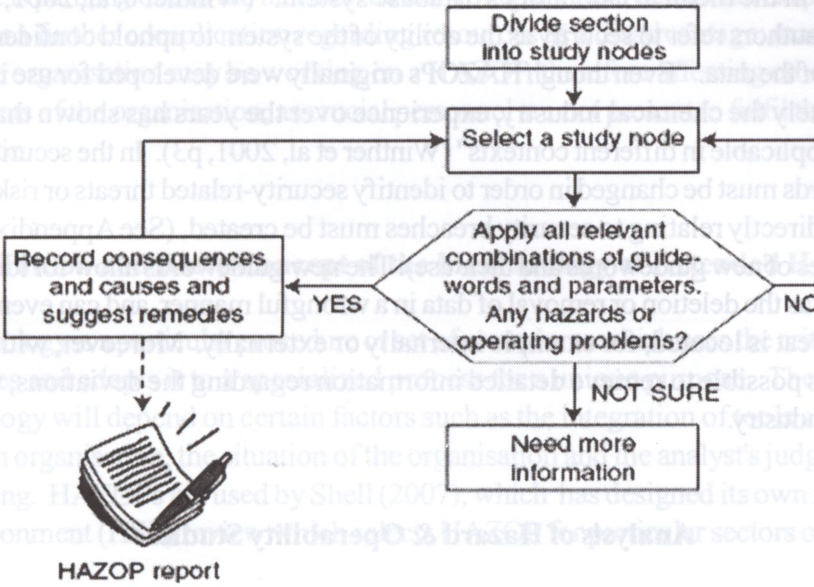
Guide-word	Meaning	Example
No (not, none)	None of the design intent is achieved	No flow when production is expected
More (more of, higher)	Quantitative increase in a parameter	Higher temperature than designed
Less (lessof, lower)	Quantitative decrease in a parameter	Lower pressure than normal
As well as (more than)	An additional activity occurs	Other valves closed at the same time (logic fault or human error)
Part of	Only some of the design intention is achieved	Only part of the system is shut down
Reverse	Logical opposite of the design intention occurs	Back-flow when the system shuts down
Other than (other)	Complete substitution - another activity takes place	Liquids in the gas piping

Figure 2.1 HAZOP Procedure Flow Chart

Figure 2.1 details a HAZOP procedure; it also demonstrates how a component is broken down into nodes, and then by applying relevant guide words will result in the establishment of possible hazards or operability problems. Record keeping is an essential part of conducting a

HAZOP study and all results must be transferred into the report, not only to record all result but to assist in future HAZOP studies.

Figure 2.1 Hazop Procedure Flow Chart



Source: Rausand, 2005, p19

Industries that Use Hazard & Operability Studies

The use of HAZOPs is not only restricted to the chemical industry. Although HAZOPs were first designed for the chemical and petrochemical industry, many companies have adopted this risk analysis technique and implemented it within their organisation as a method of risk identification and analysis. Qualitative risk analysis techniques such as HAZOPs have also now been adopted by the food and water industries, whose main concern is contamination. The pharmaceutical industry has also adopted the use of HAZOPs, and applied it to its manufacturing process, and also for evaluating process safety hazards.

The next section will reveal how the security industry has adapted the HAZOP procedure for their processes and operations especially the safety of critical systems. The security industry is currently employing HAZOPs to improve safety and security in terms of Information Communication Technology (ICT). The reason for this is due to the increasing dependency on technology. Technology permits society access to information stored electronically, e.g. the Internet, which has led to serious concerns regarding confidentiality. The security industry employs

HAZOPs due to "The fact that HAZOPs have a general practical application in diverse areas indicates that it is an excellent technique when identifying security threats" (Winther, et al 2001, p3). Due to the increasing dependency on ICT, there is a continual threat of viruses, and manipulation of data which can have serious consequences for any organisation. An example may illustrate this: "The result of a HIV-test is erroneously changed from positive to negative due to a fault in the medical laboratory's database system." (Winther et al, 2001, p1) In this example the authors refer to security as the ability of the system to uphold confidentiality and the integrity of the data. "Even though HAZOPs originally were developed for use in a specific context, namely the chemical industry, experience over the years has shown that the basic principle is applicable in different contexts" (Winther et al, 2001, p3). In the security industry, the guide words must be changed in order to identify security-related threats or risks, and new guidewords directly relating to security breaches must be created. (See Appendix C, D, E & F for examples of new guidewords and their use). The new guidewords allow for identification of risks, such as the deletion or removal of data in a wrongful manner, and can even determine where the threat is located, for example internally or externally. Moreover, with the use of HAZOPs it is possible to retrieve detailed information regarding the deviations, which is of value to the industry.

Analysis of Hazard & Operability Studies

Advantages

A HAZOP permits an extensive examination of risk within any organisation, by identifying potential risks and hazards at all stages of the process. Normally the process is broken down into various sub-processes, providing a detailed and comprehensive study of plant operation and / or process. By reducing the process into sub-processes this provides the team with a greater appreciation of the plant or process, which in turn permits identification of further potential risks that have not been considered or identified. In addition this allows the mitigation and elimination of risk at each stage in the design, making it applicable to many processes, as it can be applied to either planned or existing processes. Another advantage is that the technique allows a creative approach where many possible hazards or potential risks can be identified that may not have been identified previously. By using imagination and brainstorming, the team may then identify risks or hazards which may be overlooked and thus fail to be eliminated, causing potential problems in the future. Another advantage of this technique is that all results are documented and presented as a HAZOP report, which contains all the findings from all the tests conducted. Lessons can be learned from previous studies and can be applied when creating new designs or processes.

Disadvantages

The main disadvantage of a HAZOP is that it is time consuming and can have resource implications, which in turn can have cost implications. There is considerable research involved prior to the study, which is time consuming in itself. Time must also be allocated to allow the teams to meet and discuss strategy and logistics. This may have a direct affect on the cost of a HAZOP. "A HAZOP can cost approximately $13,000-$25,000 per week and take approximately 1-8 weeks to complete. The chemical process industries spend an estimated $5 billion annually performing HAZOPs." (Milam, 2003, p10). The reason why they are so expensive is partially due to the fact that the team often consists of expensive specialists. This in turn has a further complication regarding resources as a disadvantage: many individuals within the organisation may be working on a HAZOP, therefore affecting other functions or departments of the organisation, as crucial personnel are not present to fulfil their designated job function.

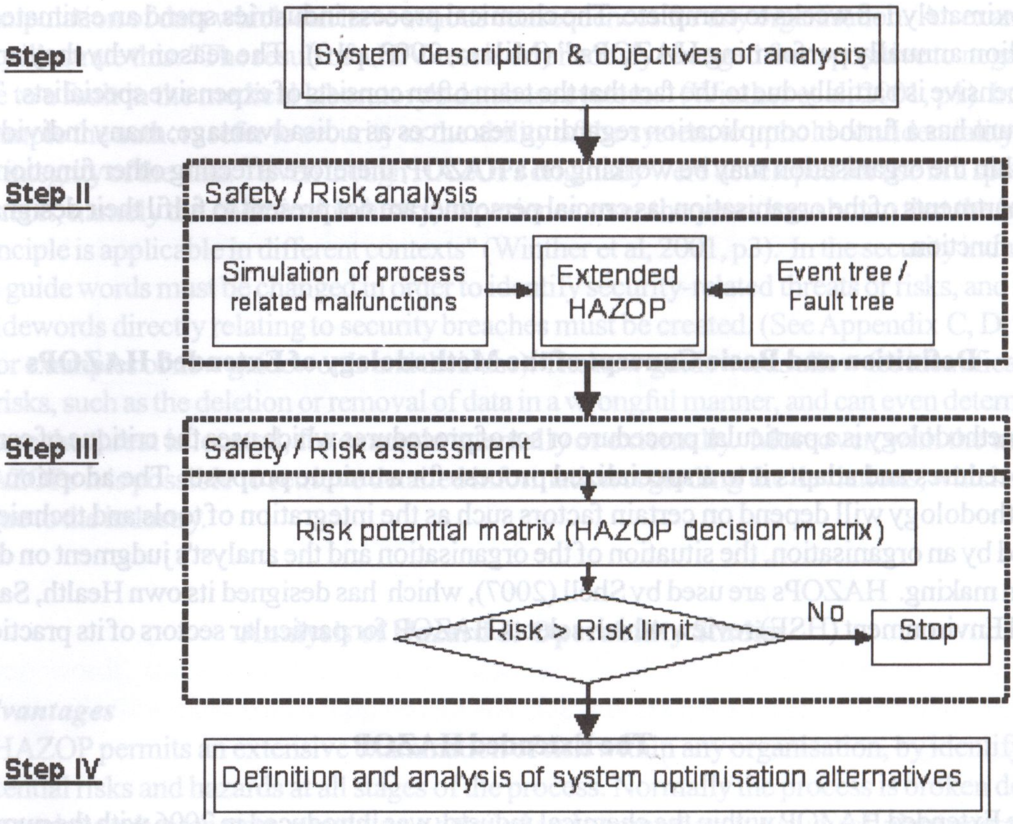
Definition and Basic Concept of the Methodology of Extended HAZOPs

A methodology is a particular procedure or set of procedures which uses the critique of certain procedures and adapts it to a specialized process for a unique purpose. The adoption of a methodology will depend on certain factors such as the integration of tools and techniques used by an organisation, the situation of the organisation and the analyst's judgment on decision making. HAZOPs are used by Shell (2007), which has designed its own Health, Safety and Environment (HSE) review which selects HAZOP for particular sectors of its practice. .

The Extended HAZOP

The Extended HAZOP within the chemical industry was introduced in 2006 with the purpose of being a a form of qualitative identification analysis. Its intention is "to identify weak points arising from disturbances in operation, which may or may not be hazardous, to improve safety, operability, and/or profit at the same time" (Ramzan et al, 2006, p37). The Extended HAZOP specifically includes dynamic simulation whilst using key areas from the standard HAZOP and the event/fault tree to assess probabilities and consequences. 'EngD' is a project, by the Centre for Innovative and Collaborative Engineering (CICE), which is similar to the Extended HAZOP methodology in its application . This investigation has demonstrated the feasibility of employing a state-based qualitative simulation (CICE (2005)). This is beneficial as it covers a broad range of operating instructions and can develop models for alternative components. The Extended HAZOP consists of four steps as can be seen in figure 5.1.

Figure 5.1 Simplified Block Diagram



Source: (Ramzan et al, 2006, p36)

The first step is very similar to the standard HAZOPs 'Intention' stage referred to in section 1.1. Objectives, parameters and purpose are defined including information gathering and team assembly. The second step involves the application of dynamic simulation. This is used to replicate the dynamic behaviour of an individual process through the effects of major deviations of design, and operational parameters, disturbances, and malfunctions of components - enabling these disturbances and failures to be thoroughly examined. This will allow safety from risks to be improved. Hysys, Speedup, gPROMS and Aspen dynamic are simulation techniques available for dynamic simulation. However Aspen dynamics is now the preferred choice due to its purpose of examining operational processes and control alternatives. Results after dynamic simulation are documented in a worksheet adapted for Extended HAZOP (See Appendix G). The third step involves results and class (frequency and consequence FC) ratings, along with the recommended actions class, being transferred into the risk potential matrix (See Appendix H). This allows prioritisation of the risks identified by placing them into a risk category/cell. The grid is divided into four levels:

- Level 1: Circumstance is unbearable and instant action is required to lower risk.
- Level 2: Circumstance is bearable but not for an extensive period of time.
- Level 3: Circumstance is adequate and any action to lower risk is optional.
- Level 4: Circumstance needs no completion.

This allows documentation of present status and future status of plant safety, and highlights the importance for action to meet the industry's safety. The fourth step involves the generation and evaluation of safety proposals. An optimum safety meeting is arranged to uncover the opinion for each safety proposal. Proposals are advanced at two levels; simple proposals (e.g. introducing sensors or gauges) or proposals related to severe circumstances (e.g. using the risk potential matrix to find solutions effects). All proposals are evaluated by dynamic simulation and/or event/fault tree analysis.

The Differences between a Standard HAZOP and an Extended HAZOP

Ramzan et al (2006) portray five main differences between a Standard HAZOP and an Extended HAZOP. The first difference is the use of dynamic simulation; the dynamic simulation is used to replicate the dynamic behaviour of individual processes. Standard HAZOPs are carried out by studying processes currently emplaced. The second key difference is the classification of risk consequences in the extended HAZOP, each recognized risk is ranked by a consequence class (called C) ranging from zero to eight, zero being no risk and eight being a major risk. See appendix I, which shows classifications of consequences with their estimated financial loss and their effects on the sector. The third inherent difference is the classification of frequency, which is very similar to the above classification of risk consequences. Frequency (called F) ranges from nine to zero, nine equalling small chance of occurrence whilst zero being highly likely. The probabilities are supported by the event/fault tree analysis. Refer to Appendix J, as it shows classifications of frequency with estimated occurrence and comprehension. The fourth difference is in the method of documenting the results: the Extended HAZOP results are documented within an altered worksheet (Appendix G) compared to a standard HAZOP (Appendix B). For the Extended HAZOP worksheet, consequences are split into two categories: physical scenario and risk related, enabling feedback on the physical scenario and the risk it imposes to that scenario. Another difference in the Extended HAZOP worksheet is each consequence and recommended action has its own frequency and consequence (FC) class established. The fifth and final difference is in the method of ranking the results. The Extended HAZOP makes use of a risk potential matrix where the risks are placed for prioritisation and documentation, and to show the future status of risks. A standard HAZOP does not make use of a matrix unless it is used as a separate technique.

Advantages and Disadvantages of the Extended HAZOP

The Extended HAZOP has additional advantages over a standard HAZOP which improves the proactive effectiveness of the risk analysis. Its dynamic simulation could be used for training purposes as well as identification of risks. It furthermore has the ability to test new modifications implemented to processes, in addition to searching for defaults. The Extended HAZOPs' capability of omitting risks is less, due to all processes being linked and visualised by a team of experts. Risks are classified in terms of frequency and consequence enabling prioritisation, which is not possible in a standard HAZOP. However a minor disadvantage is the additional cost and complexity of undertaking the dynamic simulation. Additionally a greater degree of accuracy is required when inputting data if the accuracy of results is to be obtained. Therefore, it can be noted that for a thorough analysis of risks, an extended HAZOP analysis will provide a higher accuracy at analysing deviations but at the expense of higher costs and more time.

Conclusion

In conclusion it is clear to see that HAZOPs are of value to many industries when identifying and analysing risks in an organisation. HAZOPs can prevent many hazards and risks from occurring through the detailed examination of a process or procedure. HAZOPs are applicable to a range of industries, as the method can effectively be transferred to various systems by altering or amending the guidewords to the required fields in order to provide an accurate identification of any specific risks. Extended HAZOPs have shown that HAZOPs can be united with other techniques / methods to increase efficiency and gain further benefits. That many different industries have adopted this method indicates versatility: from having been created for the chemical industry it is now being applied in the pharmaceutical industry, the food and water industry, the petroleum industry and the security industry. This demonstrates a valuable and versatile technique for the identification and analysis of risks or hazards. The consequences have been the maintenance of safer working places and practice. Although HAZOPs and Extended HAZOPs can present a considerable expense for organisations and can have other implications such as resources and time, the cost of prevention of an event has proven on many occasions to be far less expensive than suffering the event itself. HAZOP can provide a considerable amount of information regarding hazards and risks to any organisations, thus making the technique extremely valuable to any organisation or team requiring the analysis of inherent risks or hazards within their organisation.

REFERENCES

Bensard, D.; Greathead, D.; Baxter, G (2004), *When Mental Models Go Wrong. Co-occurrences in Dynamic, Critical Systems*, Journal of Human-Computer Studies, Vol 60, pp 117-128.

Cox, L.A.; Djangir Babayev, Djangir; Huber, William (2005), *Risk Analysis Journal*, Vol 25, No 3, Pp651-662.

Milam, D.E. (2003), *Synthesizing Modular Logic Models of Chemical Engineering Process Equipment and Control Systems for Verification*.

Ramzan, N., Compart, F. and Witt W. (2006) *Methodology for the Generation and Evaluation of Safety System Alternatives Based on Extended HAZOP*, Wiley.

Rausand. M. (2005), *System Reliability Theory*, 2nd Edition, Wiley.

United States Coast Guard, (2006), Risk-based Decision-Making Guidelines, *Risk Assessment Tools Reference*, Vol 3, Chapter 8, Hazard and Operability Analysis.

Winther, R.; Johnsen, O.; Gran, B. A. (2001), *Security Assessments of Safety Critical Systems Using HAZOPs*.

Internet Sites Viewed:

ASME. (2006). Safety & Risk Assessment, Identifying potential Hazardous Scenarios. Available from: www.professionalpractice.asme.org/engineering/risk/3.htm (Accessed 1 March 2006).

Centre for Innovative and Collaborative Engineering (2005). Newsletter, Available from: www.lboro.ac.uk/cice/downloads/26867%20CICE%204pp%20News letter.pdf (Accessed 28 February 2007).

Dyadem (2006). Industry Overview. The current situation. Available from: http://www.dyadem.com/company/industries/chemical/ (Accessed 28 February 2006).

Homeland Security United States Coast Guard. (2006). Risk Based Decision Making Guidelines, Vol 3, Risk Assessment Tools, Chapter 8, Hazard & Operability (Hazop) Analysis. Available from: http://www.uscg.mil/hq/g-m/risk/e-guidelines/RBDM/html/vol3/08/v3-08-cont.htm (Accessed 3 March 2006).

Lihou Technical & Software Services (2006). Hazard & Operability Studies. Available from: http://www.lihoutech.com/hzp1frm.htm (Accessed 7 March 2006).

P&I Design Ltd (2005). HAZOPs. Available from: http://www.pidesign.co.uk/hazop.htm (Accessed 7th March 2006).

O'Donnell Consulting Engineers Inc (2006). Hazard and Operability Studies. Available from: http://www.odonnellconsulting.com/hazops.html (Accessed 17 February 2006).

Risk Analysis Homepage (2006). Risk Analysis methodologies, Hazard & Operability Studies (HAZOP). Available from: http://home1.pacific.net.sg/~thk/risk.html#1.2%20Hazard%20and%20Operability%20studies(HAZOP) (Accessed 8 March 2006).

Shell (2007). Health, safety and environment review, Available from: www.shell.com (Accessed 2nd March 2007).

University of Florida (2001) Hazard & Operability HazOp Studies. Available from: http://pie.che.ufl.edu/guides/hazop/ (Accessed 26 February 2006).
Worley Parsons (2003). Hazard & Operability Studies. Available from: http://www.wsrm.com.au/hazard_&_operability.htm (Accessed 1 March 2006).

APPENDICES

Appendix A:
Example of Qualitative Risk Assessment Frame work from Australia

Table 1. Qualitative Risk Assessment Framework from Australia

Factor	Definition	Negligible	Low	Medium	High
Hazard = source of risk	Antibiotic-resistant microorganisms or their resistance plasmids (that have the potential to transfer to humans) within an animal species, arising from the use of an antibiotic in an animal species				
Exposure	Amount and frequency of exposure of susceptible humans to antibiotic-resistant microorganisms (or their plasmids) from animal sources				
Impact	The evaluation of infections (caused by antibiotic-resistant pathogens of animal origin) in susceptible humans. Considers: (1) Perceived or known clinical importance of the class of antibiotics to humans; (2) Dose response assessment of relationship between frequency and magnitude of exposure of humans (dose) to antibiotic-resistant food-borne microorganisms and severity and/or frequency of the impact (response), including an estimate of the critical threshold of exposure required to cause infection in susceptible humans; (3) Antibiotic-resistant disease severity, morbidity, mortality; (4) Expected numbers of infections and deaths; (5) The impact on human health and quality of life, including the range of susceptible humans expected to be affected. Probability of antibiotic-resistant infection development in susceptible humans (N = negligible, L = low, M = medium, H = high)				

Source: Adapted from Australia National Registration Authority Veterinary Requirements Series, Part 10 (http://www.apvma.gov.au/guidelines/vetguideline10.pdf).

Source: Cox, 652, 2005, p252).

Appendix B:

This is an actual example of a Hazop Worksheet from the United States Coast guard. (USCG). This worksheet displays the possible causes for any deviation, the related consequences of the deviation, and also the appropriate safeguards that should be applied to control the risk.

Example guide word analysis documentation

Item Number	Deviation	Causes	Consequences	Safeguards	Recommendations
		1.0 STEP - REVIEW APPROPRIATE DOCUMENTS, CHECK LOGS, ETC.			
1.1	Missing		No missing steps were identified		
1.2	Skip	Communication barriers with foreign languages Many inspection agencies on board (immigrations, customs) that do not allow adequate time to communicate expectations Time constraints on vessels trying to leave port quickly with pressure to perform rapid inspection/test	Potential to skip later steps because Coast Guard expectations are not communicated to the crew, creating the potential for accident/injury or loss of commerce Potential for inexperienced crew to perform the test, with the potential for accident or injury later in the test Potential for loss of commerce due to delay in passing the inspection/drill Vessel may be held to an inappropriate standard (i.e., drill is not conducted for the correct vessel)	Flexibility of the Coast Guard to work with portions of the crew, so that other portions of the crew can work with other agencies Standardized Coast Guard expectations that are conducted/communicated very frequently Minimum of two Coast Guard staff members, with at least one being well trained	
1.3	Part of	Same as skip			
1.4	More	Same as skip			
1.5	Less	Same as skip			
1.6	Out of Sequence	No consequence of interest if performed before the drill Same as skip if performed after the drill			

Source: United States Coast Guard, 2006, p12.

Appendix C:
This demonstrates the new way in which guidewords have been created to suit the security processes.

Pre-Guideword	Attribute	*of*	comp.	*due to*	Post-Guideword
Deliberate	manipulation	of	firewall	due to	insider
Unintentional	denial	of	service	due to	technical failure

Source: Winther wet al, 2001, p4 .

Appendix D:
This demonstrates guidewords that are suitable for identifying security threats.

Pre-Guideword	Attribute		Post-Guideword
Deliberate	Disclosure		Insider
	Manipulation	*of COMPONENT due to*	Outsider
Unintentional	Denial		Technical failure

Source: Winther et al, 2001, p4.

Appendix E:
This is a more specific example of expressions used in the identification of security threats.

Expression	Possible security threats
Unintentional fabrication of mail due to virus	Improper handling of mail attachments. Inadequate virus protection.
Deliberate disclosure of patient records due to social manipulation	Improper handling of requests for information from unknown persons.

Source: Winther et al, 2001, p5.

Appendix F:

This is simply a continuation of guidewords, showing an extensive list of attributes and post-guidewords that can be used for identifying security risks.

Attributes	Post-Guidewords
disclosure, manipulation, disconnection, fabrication, delay, corruption, deletion, removal, stopping, destabilisation, capacity reduction, destruction, denial	insider, outsider, technical failure, virus, ignorance, fire, faulty auxiliary equipment, sabotage, broken cable, logical problems, logical attack, planned work, configuration fault, spamming, social manipulation

Source: Winther et al, 2001, p5.

Appendix G:

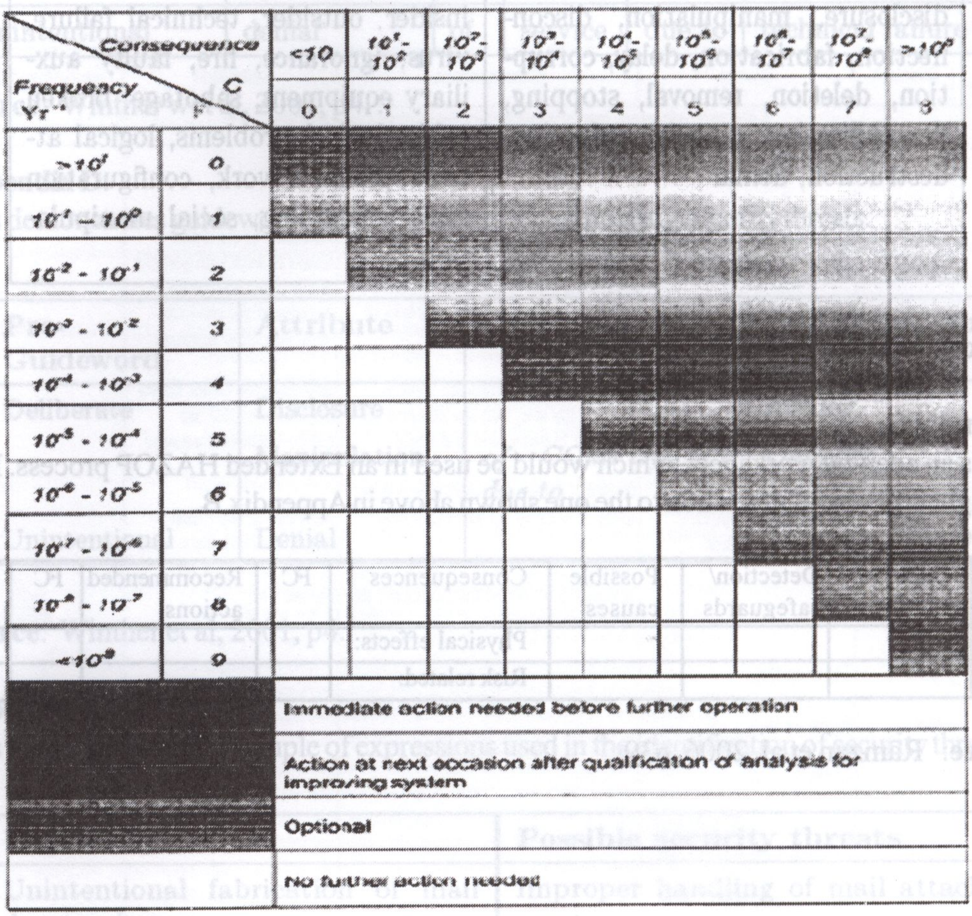
This is an adapted worksheet, which would be used in an Extended HAZOP process. Note the slight differences in relation to the one shown above in Appendix B.

No.	Guide word	Detection/ safeguards	Possible causes	Consequences	FC	Recommended actions	FC	Ref.
				Physical effects:				
				Risk related:				

Source: Ramzan et al, 2006, p39.

Appendix H:

This is an example of a 'Risk potential Matrix', which would be used in the Extended HAZOP process for prioritisation of potential hazards and risks. Note that the cells in the top right corner of the matrix have higher risks.



Source: Ramzan et al, 2006, p40.

Appendix I:

The below table shows the class and its related consequence, and is used to categorise the hazards and risks when using an extended HAZOP. It is important to note that in comparison with the standard HAZOP there no distinct classification of Risks in terms of their consequence

Class	Financial loss (Euro)	Effects
0	<10	No effects on people
1	10 - 10^2	Nuisance effect
2	10^2 - 10^3	Minor irritation effect to people and local news
3	10^3- 10^4	Moderate irritation effects to people and non-compliance to laws, local news
4	10^4 - 10^5	Moderate irritation effects to people and environments, single injuries and regional news
5	10^5 - 10^6	Significant effects to people and environment; >1 injuries and regional news
6	10^6 - 10^7	Major effects to people and environment, multiple injuries, fatality likely; regional news
7	10^7 - 10^8	Severe effects to people and environment, fatality; regional news
8	> 10^8	Multiple fatalities and process shutdown certain: international news

Source: Ramzan et al, 2006, p38.

Appendix J:

This table shows classifications of frequency with estimated occurrence and comprehension. Together with the class of consequences and the use of the forementioned Matrix, a very clear prioritisation of risks can be achieved.

Class	Frequency	Comprehension
9	<10e-8	Very very small
8	10e-8 to 10e-7	Very small
7	10e-7 to 10e-6	Small
6	10e-6 to 10e-5	Less small
5	10e-5 to 10e-4	Moderate
4	10e-4 to 10e-3	Less moderate
3	10e-3 to 10e-2	Less high
2	10e-2 to 10e-1	High
1	10e-1 to 10e0	Very high
0	>10e0	Very very high

Source: Ramzan et al, 2006, p39.