Enhancing Safety and Risk Management, from Conception to Delivery – Integrating Lessons and Good Practices to Maximise the Performance of HAZOP (and Similar) Studies

Fillipe Dobbin Caruso, Risk & Safety Engineer

Bureau Veritas UK, 66 Prescot Street, London, E1 8HG, UK

e-mail: fillipe.dobbin-caruso@uk.bureauveritas.com

Risk assessment methodologies such as Hazard and Operability (HAZOP) and Hazard Identification (HAZID) studies are broadly established across the industry as best practices for hazard identification and evaluation. Despite the level of knowledge built to date, and the extensive researches and studies carried out in the past with focus in discussing their weaknesses, constraints and areas for improvement, techniques such as HAZOP still face challenges common to any risk assessment process. Such challenges include, for example; ensuring that all potential hazards and risks have been effectively covered for the whole scope of the assessment; promoting clear communications and the understanding of the risk assessment results from all key stakeholders, and; ensuring that the optimal safety and risk management performance is delivered, maintained and continuously improved. This paper presents lessons and good practices drawn from relevant applications of risk assessment techniques in the industry; compiling and discussing different approaches for improving the HAZOP development and strengthening its role within a process safety management remit. The discussions included: the initiation of the HAZOP, with focus on the process segmentation; improved reporting and targeted presentation of results; the role of a HAZOP as part of a wider risk management process and its relationship with other risk studies. As a result, it is intended to demonstrate how a HAZOP can effectively inform and improve the decision-making process and become a valuable asset to maximise the delivery of safety and operational performances.

INTRODUCTION

Traditional risk assessment methodologies, such as Hazard and Operability (HAZOP) and Hazard Identification (HAZID) studies, are broadly recognised as international best practice techniques for systematic and structured hazard identification and evaluation. These analyses play a core role within the organisations' safety management systems. Mostly intuitive and qualitative, these methods bring together the expertise and knowledge of a wide array of professionals from different areas and backgrounds, to identify and manage potential risks to safety and to the businesses. This supports not only a thorough understanding of risks involved in facilities, tasks and operations, but also help on building a strong safety culture among the workforce. Moreover, HAZOP and similar risk assessment techniques can demonstrate to stakeholders a due commitment to plant safety and reliability.

HAZOP and similar methodologies are broadly established across varied industry sectors. However, despite the level of knowledge built to date, and even with extensive focus being given in past researches and studies to discuss their weaknesses, constraints and potential areas for improvement, risk assessment techniques such as HAZOP still face ordinary challenges when appreciated from a wider risk management perspective.

This paper discusses some key topics focused on enhancing the effectiveness of the HAZOP process, in terms of facilitating the implementation of the technique, ensuring completeness of the risk assessment, and also improving the presentation of results and the communication with stakeholders. The scope of the paper is not intended to be exhaustive and certainly not limiting; it is targeted however to address specific topics and considerations on improvement opportunities that as of yet have not been widely discussed in the literature.

In summary, this paper covers:

- The HAZOP as an element of a wider risk management process;
- Efficient process segmentation;
- Presentation of results and improved reporting, with target-oriented outputs;
- The HAZOP as an effective tool for decision making.

The paper presents lessons and good practices drawn from relevant cases and varied knowledge gathered from the industry. As a result, it is intended to demonstrate how HAZOP (and similar) studies can effectively inform and improve the decision-making process within organisations and become a valuable asset to maximise the delivery of safety and operational performances.

CHALLENGES OF IMPLEMENTING A HAZOP

The development of a HAZOP faces challenges common to any risk assessment process. From the workshop preparation until the delivery of its final results, several factors must be managed so as to not compromise the efficiency of performance of the HAZOP. Things such as, for example, having an experienced and diversified HAZOP team, with experienced facilitator, are certainly crucial for the success of the process; the same as having reliable documentation and information for the study to be based upon. Such examples are commonly and widely known as key success factors for any HAZOP. There are, however, further concerns that need to be understood and properly addressed when the HAZOP is inserted into a wider risk management context.

Outputs from a HAZOP workshop are normally composed of a hazards log and lists of recommendations. Depending on the nature of the process or facility, and also on the stage when the assessment is carried out (e.g. during FEED, or in operation), these outputs can be extensively detailed and long. Such complexity may lead to a difficult presentation, communication, interpretation, and ultimately implementation of the HAZOP results.

As an example, a HAZOP carried out for an offshore Oil & Gas production facility during FEED can generate more than 200 recommendations and over 500 pages long hazards log spreadsheets. In such a case, the HAZOP workshops could be conducted based on more than 100 P&ID's, covering over 80 different process nodes. Moreover, these workshops could involve a wide-raging variety of personnel (e.g. the facility designer, the plant operator, vendors, managers etc.), and take place throughout several months of work to be concluded.

In a situation like the above, the following concerns can be raised and, if not properly answered, jeopardize the final goal the HAZOP study:

1. How can one assure that all possible hazards have been effectively covered for the whole facility?
2. How to effectively communicate the HAZOP results and conclusions to all stakeholders?
3. How to ensure that optimal performance (and thus maximum value) is delivered at the end of this process?

To answer the above questions, the following sections discuss key aspects of the HAZOP process – from its initiation (focused on segmentation) until the final delivery of results – and also how it integrates into the wider risk management process.

THE HAZOP AS PART OF THE RISK MANAGEMENT PROCESS

The first step to determining how one can maximise the performance and added value of a HAZOP is to understand it as an element of the 'Risk Management Process', and how the HAZOP goals are connected to the other key aspects and components of such wider process.

Among its several principles, the BS ISO 31000 Standard (2009) states that 'Risk Management':

- Is an integral part of all organisational processes;
- Should be tailored to the nature of business, and;
- Should support continual improvement.

The Standard also emphasises that risk management is a crucial part of decision making, as it "*helps decision makers make informed choices, prioritize actions and distinguish among alternative courses of action"*.

The BS ISO 31000 defines the key elements of the Risk Management process (depicted in Figure 1). The 'Risk Assessment' element – which is composed of Risk Identification, Analysis and Evaluation – is central to the risk management. The other key elements – and how they interact as part of the process – are as follows:

- *Establishing the context* – takes place prior to the risk assessment;
- *Risk treatment* – is conducted after the risk assessment;
- *Communication and Consultation* – is a continual activity, in parallel with all process stages;
- *Monitoring and Review* – in parallel with all stages and in a cycle; after the risk treatment and input to establishing the context.

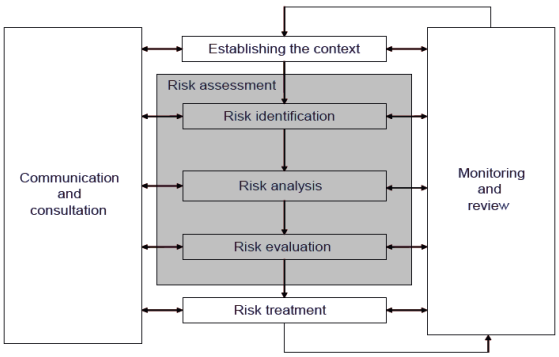

Figure 1. Risk Management Process (*Source*: BS ISO 31000:2009)

For a HAZOP, the risk assessment element (central area in Figure 1) usually accounts for the stages of preparation, development of the workshop, through to the generation of results. Other key components can be translated, for example, into the following:

- Defining the scope, objectives and boundaries of the risk assessment;
- Establishing the basis for the analysis, limitations and assumptions;
- Defining the risk criteria;
- Building up a proper HAZOP team, bringing together different areas of expertise and ensuring that different views are appropriately considered in evaluating risks;

- Communicating the results with stakeholders;
- Following-up on findings and actions;
- Continuous monitoring to ensure assumptions on which the risk assessment is based remain valid and controls remain effective.

The risk assessment is the core of the risk management process, and hence its crucial role in ensuring that maximum performance is delivered, maintained, and continuously improved throughout the wider process. The following sections will look into essential elements that form part of a HAZOP study.

PROCESS SEGMENTATION

Segmentation is a key factor for any successful risk assessment. In terms of HAZOP, the process (or system) segments are also called HAZOP nodes. These nodes account for small sections of the overall process in which typically constant and common conditions are observed – e.g. flow streams, temperature, pressure etc. Within such nodes, there will be specific pieces of equipment and process components through which the HAZOP shall investigate the potential hazards that may take place, its causes, and what may the likely consequences be.

The main point of carrying out a thorough and efficient segmentation is that, after the overall process is broken down into several 'smaller environments', there is significantly more clarity and traceability of the points where the HAZOP concerns are raised. This should give clear assurance and confidence about the coverage of the assessment, ensuring no areas of the process were missed. Based on the structured nature of the HAZOP methodology, after investigating one node after another, step-by-step, moving from one small section to the next - when all pieces of the process are covered under a specific node - one will ultimately come up with the full coverage of the process.

At this point, one important question to be answered is: *how comprehensive should one single node be*?

As a general rule, excessively small nodes will lead to an over scrutinised and detailed assessment, which is likely to result in outputs that are confusing, not concise, unclear, and generally overburdened as to its level of detail of information. On the other hand, extensive nodes will normally result in a superficial assessment, which might miss key aspects of the process, and will ultimately fail to provide the assurance that the HAZOP has been comprehensively and effectively deployed.

One crucial rule that should be followed when assessing a specific node is:

The investigation of deviations pertaining to one node shall be limited to the causes that can be specifically originated in the node, whereas the associated consequences may take place anywhere in the process.

For example, consider the following two examples:

1. A process segment commences in an oil/gas manifold pipework, going into a separation vessel (pressure vessel), which has a pressure control valve (PCV) on the top gas outlet line (connected to a pressure control loop, with pressure transmitters in the vessel etc.), and controls its level via a Level Control Valve (LCV) on the bottom liquid outlet;
2. Similar to the above; however, instead of having an LCV, the vessel's bottom outlet is directly connected to a centrifugal pump with Variable Speed Drive (VSD) that discharges the liquid to a downstream system.

In the first case, the investigation of deviations should be limited to the causes that can be originated by any of the following: the inlet pipework, the pressure vessel, the PCV, LCV and the pipework between them. Operability issues and human error associated with these items should be considered. A cause for a Gas Blow-by scenario in this case could be the failure of the LCV (excessive opening leading to *low level* on the vessel) - the cause is originated within the node - and the likely consequence can be overpressure in a downstream vessel, which would be in a different node.

In the second case, the node should be limited to include the liquid outlet pump (now replacing the LCV in the first scenario), and the analysis for the deviations on the *Level* parameter should be to some extent similar to the first case. However, the decision of not including any point from the discharge of the pump onwards in the node could be beneficial for assessing the parameter *Pressure.* In this case, the pump itself will play a significant in role in defining the pressure conditions in the system; therefore, when the *More Pressure* deviation is investigated in the node, for instance, the first question that the HAZOP team could naturally have is: *More pressure in the vessel; or more pressure downstream the pumps?* For the earlier, the vessel could be exposed to an overpressure scenario due to failure of the PCV (closed), for example, but this would have no relation to more pressure downstream the pumps; whereas in the latter, a malfunction of the pumps (e.g. a control failure leading to the pump discharging above the required) may lead to overpressure in the downstream pipeline, but will have no significant effect on an overpressure within the upstream vessel.

A third example could be the case where both a pump and a level control valve are installed in the bottom liquid outlet line. Usually in such case the valve would be installed downstream the pump to regulate the discharge flow throughput as means of controlling the level within the vessel. In this case, it would be advantageous to include up to the level control valve in the node, as this would facilitate the assessment of the *Level* parameter, without causing significant disturbances to the assessment of *Pressure* within the node.

Another point to consider is the case when the HAZOP results are to be used as input for developing a Quantitative Risk Assessment (QRA). In this scenario, one would benefit from defining the HAZOP nodes between inventory limiting valves, such as *Shutdown Valves* (SDV). The scenarios in the QRAs are described as models usually limited between such SDVs or

similar equipment. Therefore, this approach should facilitate correlating the HAZOP nodes with the QRA models, and thus strengthening the linkages between both studies.

PRESENTATION OF RESULTS

Due to the complexity and level of detail normally expected from a HAZOP study and respective outputs, and given the importance of communication, monitoring and review as part of the risk management process, as previously discussed, another key challenge of the HAZOP implementation process is presenting the results clearly and concisely and, above all, ensuring that the final results address the needs of and bring value to the stakeholders.

The main objective of improving the way the HAZOP results are presented is not to generate additional information that will need to be managed somehow, and may ultimately be ignored or lost at some point in the process. The goal is exactly the opposite – to extract and aggregate the most valuable information from within the analysis that can be useful for the end users considering the varied possible audiences. It is most likely that various people that didn't participate in the workshop will have to read, understand, and go through the decision-making process based on the HAZOP report.

There are small improvements that can significantly emphasise the key outputs and messages from the risk assessment results, for example:

- Depicting key figures on graphics;
- Providing smart and target-oriented outputs (see examples discussed next);
- Listing recommendations segregated by plant/process areas, and with respective actions by the responsible disciplines (piping, electrical, process, maintenance, etc.);
- Listing recommendations associated with the scenarios of higher risk levels.

It is a good practice (for whoever that is in charge of delivering the HAZOP results) trying to anticipate who is likely to read the report. This will help on targeting the right information this person would like to see and provide an opportunity to make it easy for them to get the results.

As an example, an extremely useful information for a plant manager could be a table or a pie-chart that correlates or give statistics regarding the most critical scenarios (e.g. with the higher risks or catastrophic consequences) with their associated plant / process segments and equipment. This can be the input information needed for taking urgent corrective actions on the facilities, coordinating the works and ensuring the participation of the workforce accordingly - prioritising to tackle the high risk scenarios first and planning to work on the low risk ones in a later moment. This could ultimately result in optimised resource usage and minimised plant downtime.

To provide another example of target-oriented reporting, Figure 2 and Figure 3 below present, in two different ways, the risk ranking results for the scenarios of a HAZOP conducted for a specific process. These are based on a specific 5 x 5 Risk Matrix with three different Risk Levels (High, Medium and Low Risk), which are a combination of the Likelihood and Severity categories. The numbers on both Figures correspond to the amount of HAZOP scenarios which have been ranked to specific risk levels based on the Risk Matrix definitions.

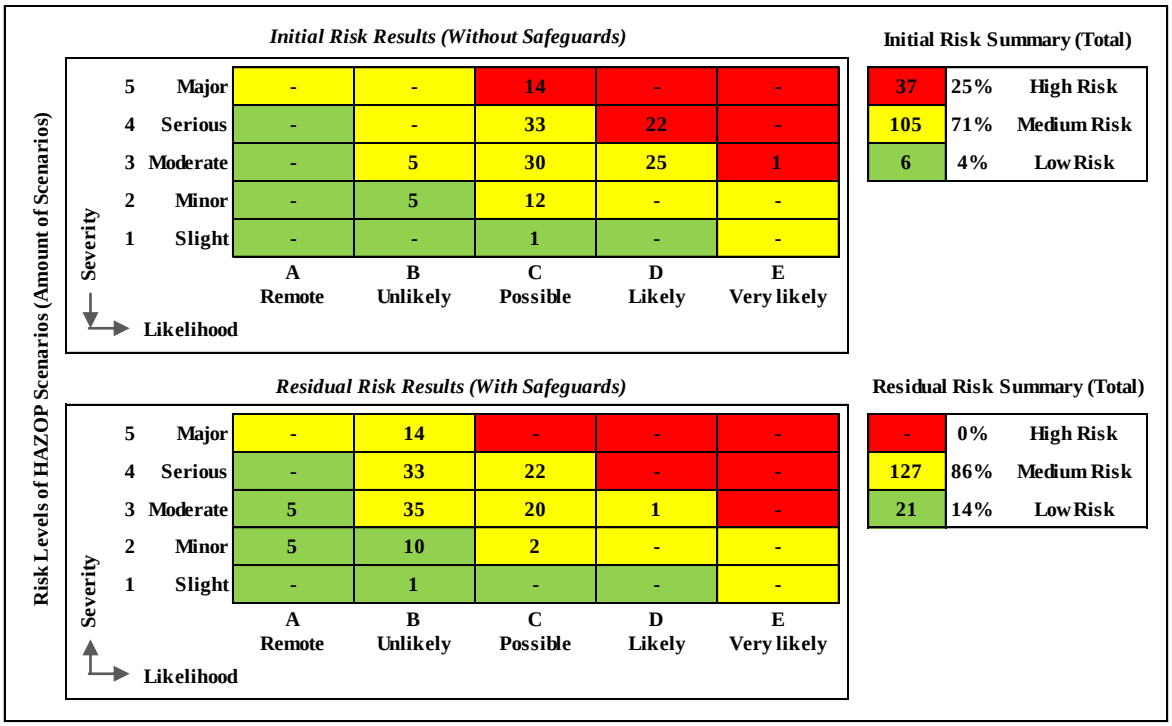

Figure 2. Example of Risk Ranking Results (Initial and Residual) using a Risk Matrix Dashboard

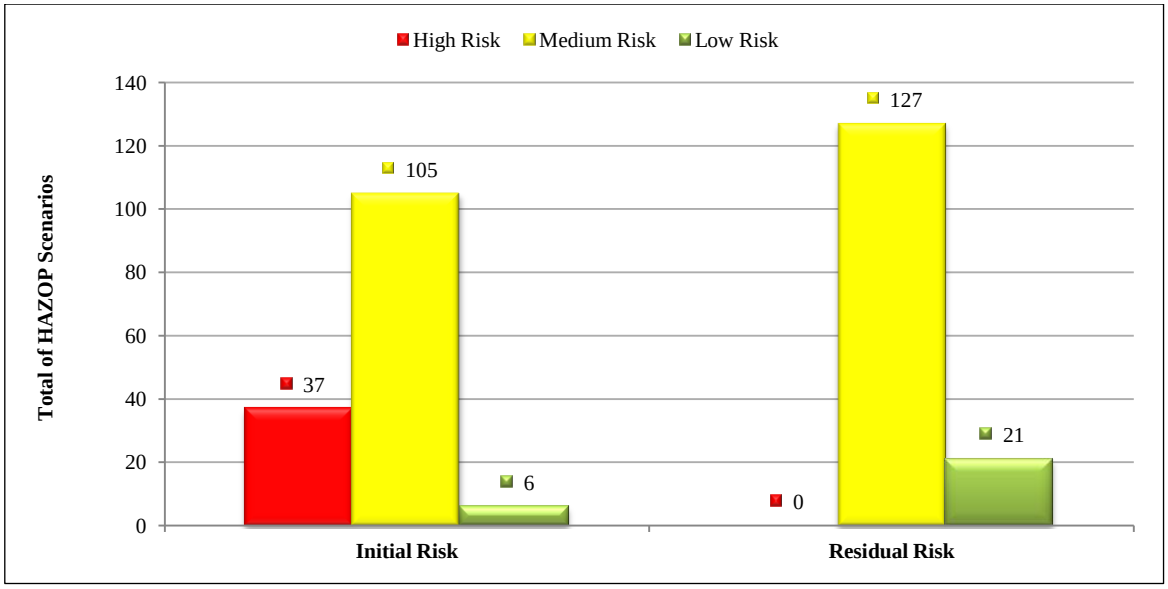

Figure 3. Example of Risk Ranking Results (Initial and Residual) on simple Chart

Both Figures 2 and 3 capture similar contents and have the same objective; however Figure 2 (Risk Matrix dashboard), because of how it is presented, generates additional value by providing further useful information.

In both cases, an overall picture of risk levels is provided, and also another important result is depicted – both Figures demonstrate the risk levels without *Risk Control Measures* (i.e. Safeguards) in place (also called Initial Risk) and the risk levels with such measures in place (Residual Risk). This gives a visual and clear representation of the effectiveness of existing safeguards in reducing the risk levels of the HAZOP scenarios.

The advantage of Figure 2 is that it details the risk levels statistics across the whole Likelihood-Severity spectrum of the Risk Matrix. This approach demonstrate more clearly how the various scenarios 'descend' from high to medium risk, and from medium to low risk, throughout the Risk Matrix, after the risk control measures are taken into account.

Another key benefit from the approach in Figure 2 is that it shows to which extent scenarios have been specifically ranked to '*Major Severity*' levels. This is a valuable information, usually employed in the industry, for example, in the process of identification and management of Safety-Critical Elements.

In general, many benefits can be obtained from the risk assessment's outcomes if these are reported clearly and smartly, in a way that they are easy to be understood and managed, and effectively address the needs of the end-users. Such benefits can include:

- Prioritisation and effective planning of corrective actions;
- Defining maintenance and inspection strategies and programmes, for example with *risk-based* approaches;
- Further analysing risks and managing barriers in Bowtie diagrams (which give visible representation of the scenarios, showing links between threats, hazards and consequences);
- Using the assessment as basis for detailed risk studies (e.g. Quantitative Risk Assessments, Gas Dispersion Modelling, etc.)

FINAL CONSIDERATIONS

This paper addressed challenges and improvement opportunities related to the development of HAZOP studies. The examples presented herein, however, could also be extended to similar techniques, such as HAZID. The goal of the paper was to discuss recommendations to enhance the overall performance of such studies and, as a result, it was intended to demonstrate how they can best inform and improve the decision-making process within organisations. The scope of the paper was, however, not intended to be exhaustive nor limiting. In summary, this paper focused on the following topics:

- Process segmentation as a key factor for the HAZOP implementation;
- Presentation of results - to address the needs of and be understood by the possible audiences;
- The role of risk assessment as part of the wider risk management process, and the importance of effective communication and involvement of stakeholders for a successful HAZOP delivery.

In line with what has been discussed, the following are general recommendations that should help improving the risk assessment development and ultimately ensuring that its message is effectively sent across and value is added to its final results:

- Clearly define and state the scope, boundaries, limitations, the assumptions and the basis for the analysis;

- Thoroughly define the process segments on analysis to ensure the risk assessment undergoes an optimal degree of scrutiny, so there is a clear assurance and visibility of its coverage and completeness;
- Write down a reader-centred report, but also anticipate who the target audience(s) is(are);
- Extract and aggregate the key information and messages considering the needs of the different stakeholders and the possible audiences;
- Present clear and concise conclusions, describing the linkages to the study assumptions and any other relevant sources.

To accomplish the above, it is crucial that the needs and expectations of stakeholders are identified and effectively communicated, and that parties involved in the risk assessment understand the organisation's context, its key objectives, as well as the governing processes, conditions and criteria that have been established to achieve them.

Management of information, timely analysis and action are key business factors on our new era of technology. Therefore, it is imperative that the risk assessment process, central to the risk management, is effective in delivering its intended outcomes and is efficient in doing so, so as to enable organisations to achieve optimal safety and operational performances.

REFERENCES AND BIBLIOGRAPHY

1. BS ISO 31000:2009; Risk management – Principles and guidelines, 2009, pp. 7, 8, 14
2. Crawley, F.; Tyler, B.; 2015; HAZOP: Guide to Best Practice, 3rd Edition, IChemE
3. Centre for Chemical Process Safety; 2008, Guidelines for Hazard Evaluation Procedures; 3rd Edition, AIChE
4. Verna, A.; Fernandez, S.; Stevens; G.; 2009, Improving the Performance and Consistency of HAZOP Facilitation and Recording; Hazards XXI, IChemE
5. Munn, A.; 2009, Common Problems and Recent Trends with HAZOPs; Hazards XXI, 2009, IChemE
6. Whitty, Steve; Foord, Tony; 2009, Is HAZOP Worth All the Effort it Takes?; Hazards XXI, IChemE

ACKNOWLEDGEMENT

Permission to reproduce extracts from British Standards is granted by BSI Standards Limited (BSI). No other use of this material is permitted. British Standards can be obtained in PDF or hard copy formats from the BSI online shop: www.bsigroup.com/Shop