Joining up the dots, taking the puzzle out of having "line of sight" to Major Accident Hazards.

Gaynor Woodford-Phillips & Stephen Beedle, Principal Safety Consultants, ABB Consulting, Billingham

On COMAH regulated establishments hazard identification is the key to being able to identify and select a consistent focussed representative set of major accident hazards (MAHs), identify safety critical equipment and safety critical tasks. A well-developed MAH scenario with event frequency and the number of equivalent scenarios on an establishment can then feed into the establishment occupied building risk assessment, the establishment environmental risk calculations, individual risk of fatality and societal risk calculations. MAH scenarios can also inform the development of emergency response plans.

With hindsight and examining the development of COMAH safety reports, the content and format of many reports reflects the iterations and developments in application of the regulations and is not necessarily where an Establishment would start from if creating a report from scratch.

The experience of the authors is that, despite the maturity of the COMAH regulations, establishments rarely seem to have a joined up approach in process safety risk management and COMAH report generation which results in lack of clarity both within companies themselves but also when inspected by the Competent Authority (CA). Joining up the dots leads to consistency, clarity, cost-effective process safety risk assessment and management with the benefit of reducing the inspection burden for the CA and thereby the cost of inspection to the establishment.

The purpose of this paper is to show that by having an holistic overview of the COMAH safety report and an understanding of the interaction between component parts will allow establishments to join up the dots providing a line of sight from hazard studies and hazard identification through major accident hazard selection to safeguard management, equipment maintenance and inspection, human factors, emergency response and the risk profile for the establishment.

Whatever approach is taken the depth of the analysis the CA requires that it should be proportionate to the hazards and risks presented by the establishment. The holistic approach to a COMAH safety report presented in this paper is applicable regardless of the hazards and risks and can therefore be applied proportionately.

Keywords: COMAH, Safety Critical, Major Accident Hazard (MAH)

Introduction

COMAH safety reports are complex documents. This paper begins by introducing their purpose and then at a high level suggesting the required contents by drawing on available guidance. There is discussion of how the layout and contents have evolved and how this has led to additional complexity and duplication. This paper proposes chapters to be included based on the experience of the authors with numerous clients over nearly a decade. The paper then seeks to dissect the complexity and in doing so demonstrating how the proposed structure meets the purpose of a COMAH safety report.

This paper shows how the COMAH safety report can provide a line of sight from hazard studies and hazard identification through major accident hazard selection to safeguard management, equipment maintenance and inspection, human factors, emergency response and the risk profile for the establisment. This paper suggests how this can be made a cost-effective exercise, generating a risk profile that is transparent and allows easy identification of targeted risk reduction measures.

Purpose of a COMAH Report

Part (b) Regulation 8 of the COMAH Regulations 2015, requires the operator to prepare a safety report for the purposes of demonstrating that "major accident hazards and possible major accident scenarios, in relation to the establishment, have been identified and that the necessary measures have been taken to prevent such accidents and to limit their consequences for human health and the environment".

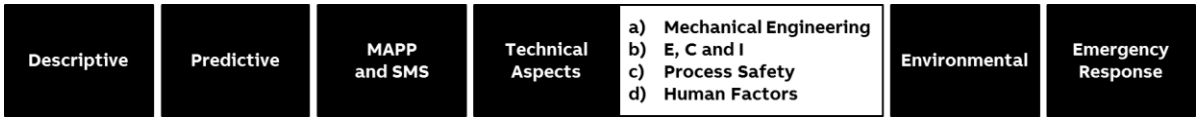
In simple terms a COMAH safety report needs to answer the following questions:

1. Is it understood what could go wrong?
2. Is it understood what systems are in place to prevent this from happening?
3. Is there information to assess that the systems are working effectively?

Overview of contents of a COMAH Report

Any COMAH safety report submitted is assessed by the CA using the Safety Report Assessment Manual (SRAM) (CA, 2015), this document in combination with the regulations and guidance on them (HSE, 2015) provides an establishment with substantial guidance on the material content required. However this guidance provides little clarity on the structure of a report but by reference to the SRAM alone an establishment COMAH safety report maybe structured as shown in Figure 1, where the Technical aspects chapter is divided into four parts: Mechanical engineering, Electrical, Control and Instrumentation, Process safety and Human factors.

Figure 1 Chapters in a COMAH safety report inferred from SRAM Guidance



By trying to match the SRAM requirements against each of the nominal chapters can lead to repetition of the same information, repetition of information can easily lead to update errors (i.e. changes not made where the same information is repeated) and also means more assessment time required by the CA. By simply aligning the report to the SRAM can also introduce problems if the CA modifies any of the SRAM criterion, as has happened historically, which then leads immediately to a misalignment between the COMAH safety report and criterion.

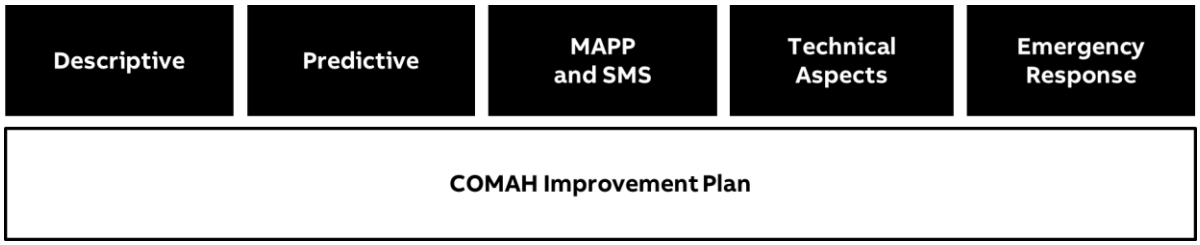
COMAH reports for long standing Upper Tier Establishments have evolved for many reasons including regulation changes, the CA honing its inspection and enforcement regime and changes to SRAM criterion. This can frequently result in an ever growing safety report including "add-ons" where additional requirements have been met.

One other evolution of COMAH safety reports is that many reports started with a full quantified risk assessment (QRA) as the risk assessment demonstration. QRAs are very detailed analysis of the risk profile for the establishment is sometimes derived from the Land Use Planning (LUP) stage before the establishment process is fully designed and constructed. QRAs can be very difficult to interrogate, they tend to use generic failure data which may not reflect the nuances of particular scenarios onsite, due to their heritage. In addition full QRAs can be difficult to update by the establishment due to either specialised knowledge and/or software. This approach can also mean that it is difficult to easily demonstrate where risk reduction should be targeted, and this paper seeks to address this by proposing a "high" level QRA to give an indicative cumulative risk where deemed proportionate.

All these evolutionary steps makes comprehension of the COMAH report contents more difficult.

Figure 2 below shows the suggested chapters in a COMAH safety report underpinned by a COMAH improvement plan, which can then be supported by a roadmap for the CA mapping SRAM criterion into the relevant chapters.

Figure 2 Proposed Chapters in a COMAH safety report



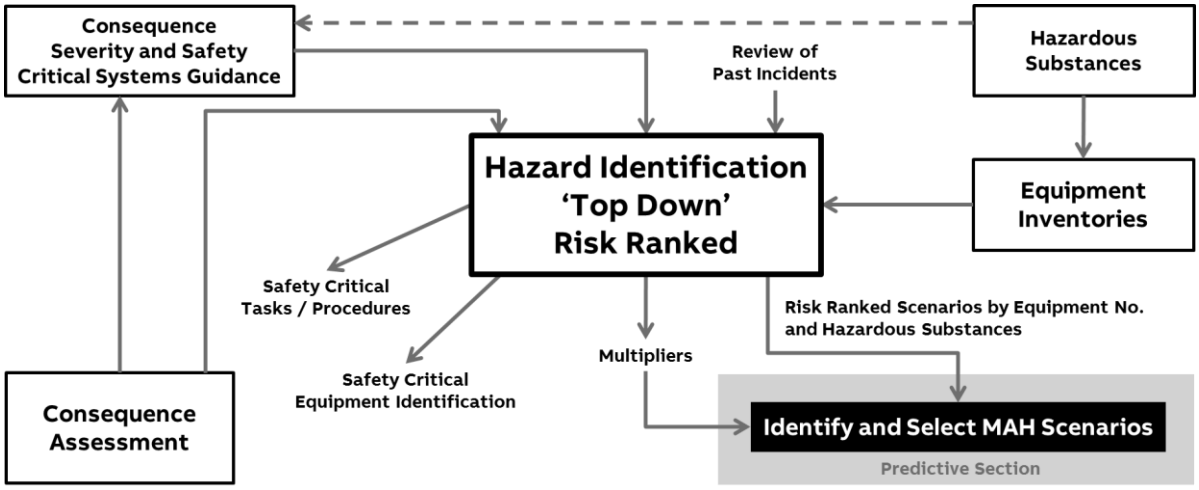
This model combines the safety and environmental risk assessment within the Predictive chapter. In simple terms the descriptive chapter can be considered an introduction to the establishment and its activities and providing context in terms of its location and its potential to cause harm to the environment and people. The predictive chapter includes the risk assessment for the establishment. The remaining three chapters MAPP & SMS, Technical aspects and emergency response provide the information to support the risk assessment (within the predictive chapter) to demonstrate that the systems and measures in place are sufficiently robust and reliable to support the risk assessment claims. The Technical aspects section is not explicitly divided into four sections in this model as all the sections are intimately linked with the predictive section and the MAH scenarios selected, as will be shown below. These proposed chapters are intended to cover all the SRAM requirements, as shown in later figures.

It is useful to consider the proposed chapters of a COMAH report and the way in which they are interlinked. By looking at it holistically and considering the interrelatedness it is possible to identify where incremental changes can be made to improve the "line of sight" through-out the safety report.

Identification of Major Accident Hazard Scenarios – is it understood what could go wrong?

The starting point for any safety report should be to answer the first question identified in the purpose i.e. is it understood what could go wrong? To demonstrate a consistent approach to MAH identification and selection reference should be made to the establishment's Hazard identification. This can take many forms, but should ideally identify all possible loss of containment scenarios. Figure 3 below provides an overview of the process of identifying and selecting major accident hazard scenarios, including some necessary inputs and useful by-products of the process and in turn where incremental improvements can be made.

Figure 3 Overview of process of MAH selection



The ideal form of hazard identification to feed into identifying MAHs is a "top down" approach such as HAZID or Process Hazard Review, which use loss of containment or ultimate consequence guidewords, rather than deviation from design guidewords methods (such as Hazard Study 3/HAZOP) (IChemE, 2000).

The "top down" approach immediately allows the screening of different consequence events. The use of HAZID output means that for a new plant the development of the MAH scenarios can be carried out early in the design process and inform the Preconstruction Safety report.

Once all MAH scenarios have been identified, for more complex establishments, this needs to be rationalised into a "representative set" i.e. groups of scenarios that are simplified into a "representative" scenario for the group which in combination with other representative scenarios can be used to represent all hazards on the establishment. The grouping needs to demonstrate why certain equipment is selected as representative, and this may not always be the "worst case" or largest inventory but may require consideration of subtleties such as proximity to different receptors or an absence of safeguards which will impact the scenario risk. This then drives the need to carry out semi quantitative risk ranking during the "top down" hazard identification to allow the risk of each scenario to be determined, which also means that at this stage there needs to be an adequate understanding of the consequences of different types of releases.

Prior consideration of the consequences of release of materials via different release type's e.g. catastrophic failure or different leak rates ahead of any hazard identification serves many purposes including:

- Consistent consequence (severity) ranking in all hazard identification studies and process safety risk assessments beyond the COMAH report.
- Identification of which release types would be considered safety critical – allows identification of safety critical systems, tasks or procedures from the "top-down" hazard identification.

One of the many historical pitfalls was not to consider the consequences in any detail until the representative set MAH scenarios were already selected this largely stemmed from the absence of risk ranking in "top down" hazard identification studies until relatively recently.

Therefore the ideal output from hazard identification to allow the selection of representative scenarios is risk ranked scenarios, linked to equipment number and hazardous substances. To select representative MAH scenarios also requires grouping of scenarios and requires an understanding of the initiating causes for events, for example causes grouped by integrity failure, control failure, human error failure. The initiating events identify the main scenarios and the primary control measures which combined with the risk ranking and hazardous substances guides the selection of any sub scenarios and sensitivity cases. As an example seal leaks on a refinery may be from pumps distributing materials which result in different consequences. For illustration there may need to be three sub scenarios a gasoline pump given rise to a pool and flash fire, an LPG pump giving rise to a flash fire or vapour cloud explosion and a gasoil pump to illustrate the environmental consequences. Once the representative MAH scenarios have been selected it is possible to sanity check the selection of scenarios versus the SRAM and the relevant safety report assessment guide (SRAG) (e.g. HSE, undated) to ensure that all likely types of scenario consequence or release type have been considered.

Another most useful output from the scenario selection when linked to hazard identification is the link to the number of similar scenarios that exist across the establishment which informs the "multipliers" that need to be applied to the cumulative risk calculations (see Figure 5) when considering the risk profile for the establishment in terms of environmental, societal and individual risk.

Other inputs and outputs from the hazard identification that can be considered as incremental improvements is the consideration of the review of incidents and the identification of additional risk reduction measures. Since the 2015 COMAH regulation revision and the specific criterion revision demonstrating a review of past incidents both internal and external has been undertaken has received increased focus from the CA. A review of relevant learning from incidents and incorporation

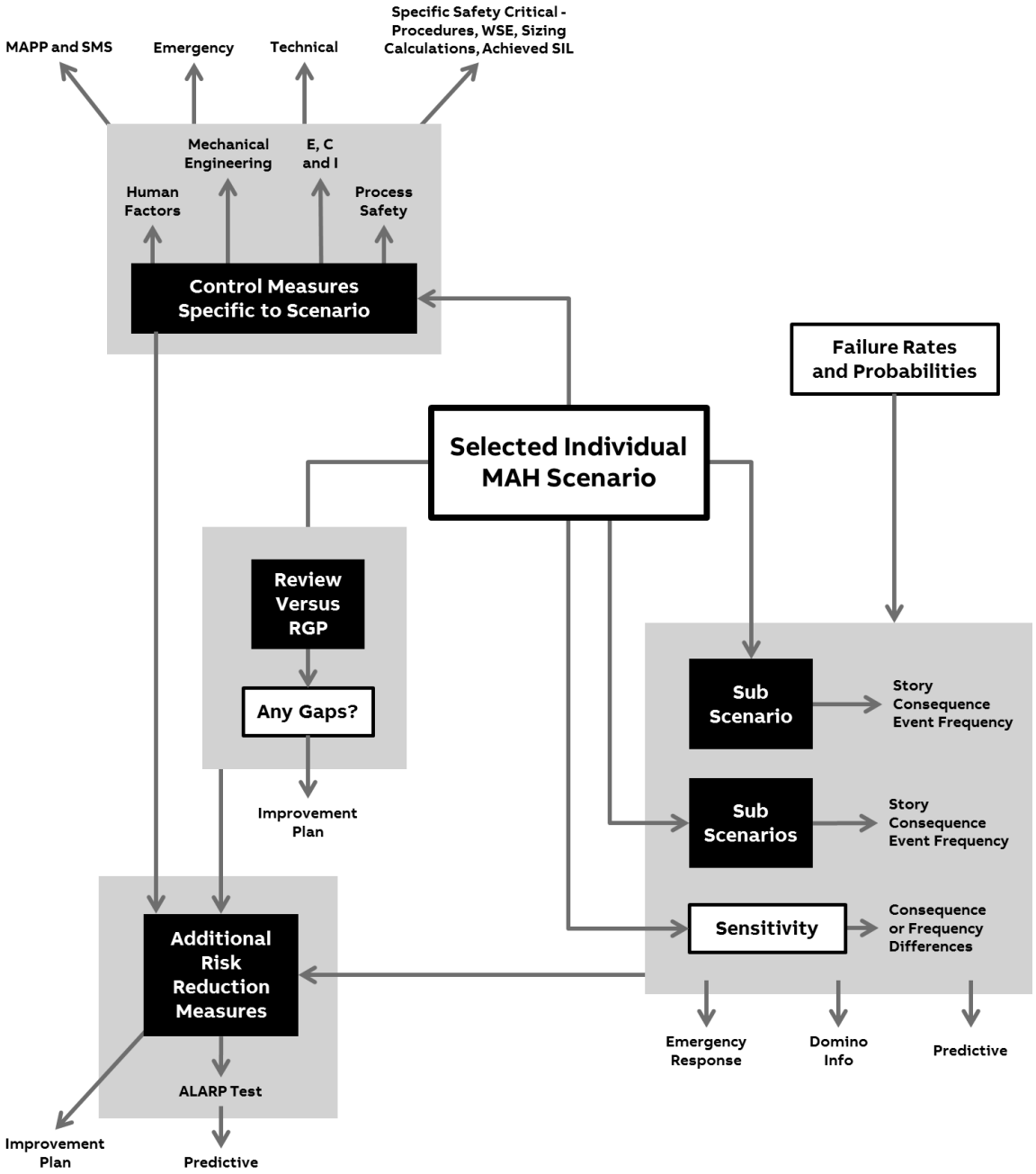
into the hazard identification is useful, by recording what safeguards or what differences exist to prevent a specific incident. This also demonstrates that an organisation is focussed on learning and improving from the lessons learnt by others. It is also worth incorporating the review of risk reduction measures into the cyclical review of the establishment hazard identification which allows for a more efficient ALARP (as low as reasonably practicable) (HSE, 2001 & CDOIF, undated) demonstration at successive COMAH safety report updates, as described below in the analysis of each selected MAH scenario. Cyclical review of the establishment hazard identification, ideally before the establishment COMAH report is resubmitted allows for the revalidation of MAH representative scenarios to be updated to reflect any changes and demonstrate improvements.

Analysis of each selected MAH scenario

Once it is understood what could go wrong the questions that need to be answered are: what systems are in place to prevent this from happening and is there information to assess that the systems are working effectively?

The MAH scenarios selected underpin the COMAH safety report and figure 4 below attempts to demonstrate the interlinking that exists between the COMAH report chapters and selected scenarios. The scenarios themselves are intended to answer – what systems are in place to prevent this from happening, and the interlinking allows for cross referencing which shows how it is possible to asses if the systems are working effectively.

Figure 4 Selected Major Accident Hazard Scenario Analysis



As discussed above MAH Scenarios are specific to the hazard identification for the establishment, therefore there is a "story" associated with how the scenario occurs, which can be derived directly from the hazard identification. In the author's experience the CA is increasingly asking for the "story" of how an event develops and its consequence to be made clearer. The "story" telling is something that is usually not included in a QRA, and may have been included as an "add-on".

A MAH scenario should ideally include the following:

- An overview – highlighting the primary control measures e.g. catastrophic tank failure the primary control measure would be integrity management. The earlier selection process (figure 3) should have included grouping scenarios by initiating causes allowing the easy identification of the primary control measures.
- For each sub scenario:
    - The "story" of how the scenario occurs and then the consequences of the release, the "story" needs to include consideration of location of personnel and their escape routes.
    - Appropriate consequence modelling data including the hazard ranges for flammable and toxic releases and environmental effects.
    - Any predicted number of fatalities and major injuries should be included to support the severity assessment for the scenario which should be consistent with the consequence severity assessment in figure 3. Where injuries are claimed, rather than fatalities, for example if escaping pool fire thermal radiation then the thermal doses and distance an individual travels should also be included.
    - The calculated event frequency. The calculation of the event frequency needs to document the initiating causes, safeguards and appropriate conditional modifiers in a similar way to a Layer of Protection Analysis (LOPA) or for more complex scenarios reference can be made to the more detailed analysis. For scenarios where safety instrumented functions are a safeguard the SIL determination can be referenced.
    - The relevant number of multipliers that need to be applied to the event frequency when considering the cumulative risk calculations.

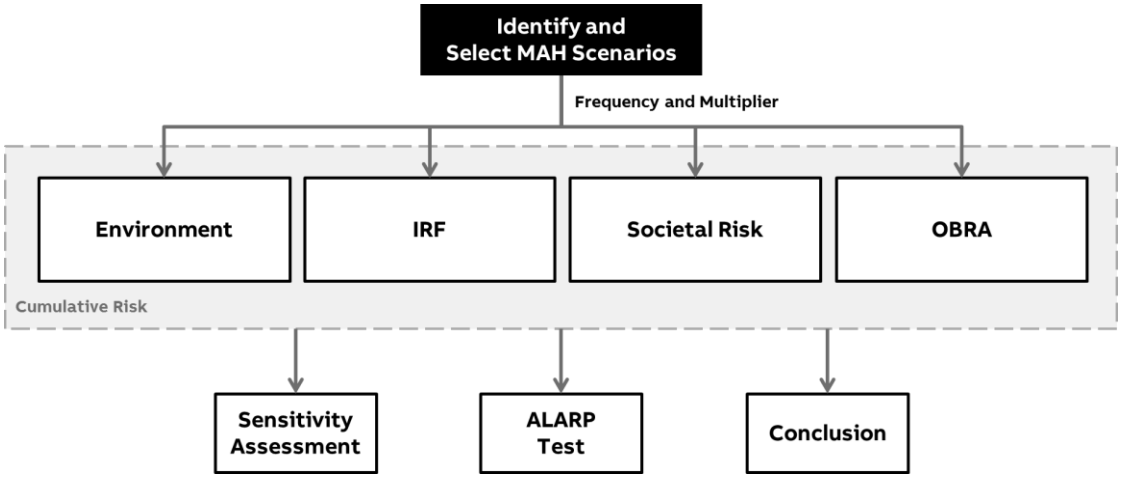
    Note a sensitivity case may not require as much detail as it is usually a slight subtlety in scenario that needs consideration at the cumulative risk calculation stage in terms of either frequency or consequence. For example an establishment with large flammable inventories and then a small methanol tank. Methanol has a lower surface emissive power and therefore smaller pool fire hazard ranges. Therefore representing the methanol pool fire case hazard ranges by the larger inventory case would skew the cumulative risk profile therefore it may be included as a sensitivity to demonstrate the differences.
- Identification of control measures specific to the scenario under consideration, the information in this part of the scenario should be used to support the calculated event frequency i.e. it should provide confidence in the reliability of the control measures. This is easily cross referenced to other chapters of the report (see Figure 4) if there is sufficient detail in those chapters, or to other documents that may be relevant to the scenario such as procedures, written schemes of examination, achieved safety integrity level (SIL) calculations, relief valve sizing calculations etc. The author's experience is that the CA will request some referenced material as required to validate the claims made. It is also worth noting that by inference any documents/processes/safeguards referenced at this stage are therefore safety critical.
- A review against the applicable relevant good practice (RGP) for the scenario under consideration, with any gaps identified. This step is required to be able to ultimately demonstrate ALARP (as low as reasonably practicable) (HSE, 2001 & CDOIF, undated). Any gaps identified need to be carried forward for consideration in the COMAH improvement plan. It is also important to be cognisant of the fact that the RGP gap analysis needs to be carried out for all equipment represented by the selected scenario i.e. the equipment identified as "multipliers" for the cumulative risk calculations.
- A review of any additional risk reduction measures that are required. This can come from the RGP review or more likely by looking at the relative event frequencies and risk ranking and considering ways in which the frequency or consequences can be reduced. This allows a focus on specific scenarios and the targeted identification of risk reduction measures something which is not easily achievable with a QRA. Again any identified measures need to be carried forward for consideration in the COMAH improvement plan and applied to all equipment represented by the scenario. The review of risk reduction measures by scenario will ultimately support whether a claim of ALARP can be made. It is also worth incorporating the review of risk reduction measures into the cyclical review of the establishment hazard identification which allows a for a more efficient ALARP demonstration at successive COMAH safety report updates, as noted above.

Predictive Chapter

Establishment risk assessment

Identifying and describing the MAHs is part of the predictive chapter which is used to demonstrate the risk profile for the establishment in terms of environmental, societal, individual risk of fatality (IRF) and occupied building risk assessment (OBRA), see Figure 5.

Figure 5 Simplified Overview of Predictive Chapter



The risk assessment draws on the event frequencies and the multipliers for similar scenarios to generate the establishment risk profile. This is a "high" level QRA which gives an indicative cumulative risk, which is supported by sensitivity assessments, but is far more time efficient and transparent compared with a full and detailed establishment QRA.

The output of the predictive chapter should include the risk profile for establishment, including a test of ALARP and a sensitivity to any of the specific parameters included in the risk assessment, as well as a conclusion. The analysis of the MAHs including compliance with RGP and consideration of additional risk reduction measures are used to support the test of ALARP, alongside any identified COMAH improvement plan items. The conclusion should draw together the findings of the risk assessment i.e. if the risk is unacceptable (HSE, 2001) what immediate measures will be taken to alter the risk profile with appropriate timescales. If the risk is in the tolerable region there should be a discussion of whether a claim is being made for the risk being ALARP or again what additional measures will be implemented to allow a claim of ALARP.

Conclusions

This paper has endeavoured to demonstrate an interpretation of the COMAH safety report structure and contents that can be used in a proportionate and time efficient way by different establishments. The paper has attempted to provide a holistic overview of the inter-related chapters within a report, highlighting the benefits of "top down" hazard identification. The paper has shown that:

- Risk ranked hazard identification with consistent consequence prediction allows the development of MAH scenario selection, identification of safety critical equipment, procedures and tasks and if used beyond the COMAH report consistent severity estimates in all process safety related risk assessments.
- Incorporation of a review of past incidents in hazard identification embeds the learning from incidents into the establishment hazard identification
- The selection and then analysis of individual establishment specific scenarios can be used to identify targeted risk reduction measures and demonstrate compliance with RGP.
- Cyclically review of the establishment hazard identification revalidates the selected MAHs, and can be used to identify additional risk reduction measures which allows a for a more efficient ALARP demonstration at successive COMAH safety report updates.
- Once the scenario frequencies are incorporated in the cumulative risk the dominant risks can be identified, further targeting risk reduction measures. This is a "high" level QRA which gives an indicative cumulative risk, which is supported by sensitivity assessments, but is far more time efficient and transparent compared with a full and detailed establishment QRA.
- By understanding the interlinked chapters within the report it is possible to reduce repetition of information and better signpost the relevant references.

Possible incremental changes that establishments could consider introducing include:

- Consistent consequence and severity guidance

- Using cyclical hazard identification studies to
    - learn from incidents
    - identify safety critical systems/equipment /procedures/tasks
    - ensure MAHs are documented
    - review additional risk reduction measures
- Include risk ranking in hazard identification studies

References

CA, 2015, Control of Major Accident Hazard Regulations 2015 (COMAH), Safety Report Assessment Manual (SRAM) - 2015, Sections 9 – 14

CDOIF, undated, Chemical & Downstream Oil Industries Forum, Guideline – Environmental Risk Tolerability for COMAH Establishments v2.0

HSE, 2015, The Control of Major Accident Hazard Regulations 2015 – Guidance on Regulations, L111 (3rd Edition), HMSO

HSE, 2001, Reducing Risks Protecting – HSE's decision making process, HMSO

HSE, undated, HID – Safety Report Assessment Guide: Highly Flammable Liquids (HFL)

IChemE, 2000 "HAZOP Guide to Best Practice"