Quantitative Risk Assessment life-cycle and methodology

Quantitative Risk Assessment (QRA) tools are used to determine, evaluate and manage high risk complex industrial processes. This paper by Amir H. Akhlaghi, Engineering Director at Functional Safety Consultancy Ltd, suggests an alternative to the generic approach that is often taken to the provision of a QRA project.

The proposed steps outlined below provide a unique approach where a QRA life-cycle is adopted and a breakdown of key phases allows for customisation of the study. Guidance is provided on potential challenges in delivering the required activities for each phase and the importance of a QRA Terms of Reference.

QRA methodology overview

The QRA methodology encompasses an array of studies, which allow for the overall risk to be derived. Figure 1 provides an overview of the QRA Life Cycle.

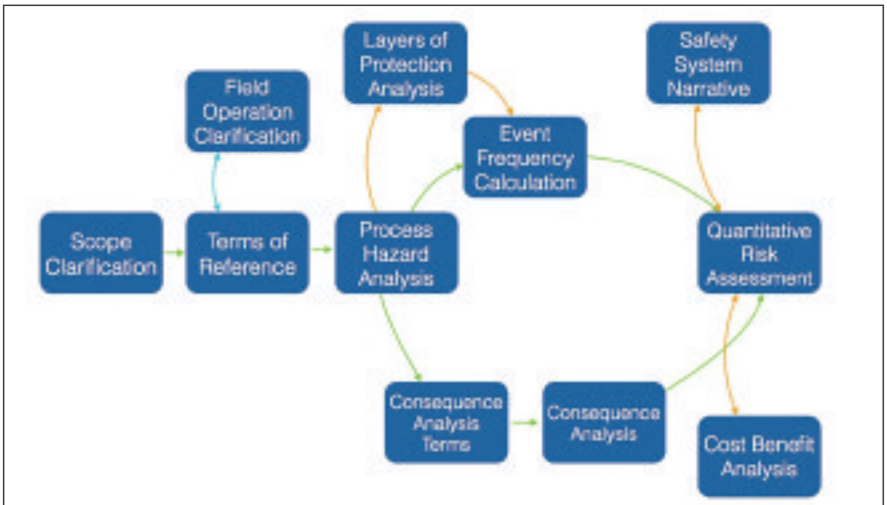

Figure 1. QRA Life Cycle

It should be noted that a detailed QRA study entails qualitative and semi-quantitative risk assessment techniques as part of the input in to the quantification of risk.

Hazard Types

Consideration should be made to all possible hazards however the following are typical examples:

- Process hazards i.e. under or over temperature or level.
- Overpressure scenarios where the process can exceed the maximum allowable operating pressure.
- Loss of containment due to leaks from flanges, valves, instrumentation and fittings.

- Corrosion and erosion.
- External impacts such as vehicle or crane impact or perhaps anchorage slippage.

QRA Life Cycle Technical Steps

1. Scope Clarification

It is essential to get full clarity on the scope of the assessment and the facilities prior to starting the collecting and collation of the data and information. This is of particular importance where perhaps the offshore and onshore portion of particular facilities are to be assessed at different times.

2. Terms of Reference

Having clarified the scope, the first step is to develop a Terms of Reference (ToR). The ToR will capture all the necessary information to initiate a QRA and will continue as a live document throughout the QRA project.

3. Field Operations Identification

Complex facilities which have different modes of operation shall be evaluated and identified. It should be noted that modes of operation may have different hazards associated with them and thus contribute differently to the total calculated risk.

4. Hazard Identification

The next step is Process Hazard Identification (PHA) which pinpoints the major causes of hazards for the facility and identifies their broad consequences. This step provides the foundations for the study, as it is a key input for the following steps and is often conducted as part of a Hazard Identification (HAZID) activity.

The HAZID is conducted to identify hazardous scenarios that could lead to significant adverse consequences. The HAZID process and brainstorming workshops qualitatively identified the potential causes, which could lead to the hazardous events. The consequence of these hazardous events are also discussed, however a detailed quantitative approach such as a Frequency Analysis is needed to calculate the rate of occurrence and detailed Consequence Analysis modelling is required in order to better ascertain the effect or effects of the identified hazardous occurrence.

5. Frequency Analysis

Frequency Analysis is carried out in two stages. Initially a semi-quantitative approach is used through the Layers of Protection Analysis (LOPA) methodology as a part of the PHA study, which determines the most significant causes of the hazards as well as protection layers which may mitigate those scenarios. Following this, Fault Tree Analysis (FTA) is employed to build a more complete picture of the different potential incidents. The preliminary LOPA allows for the identification of any Safety Integrity Level (SIL) rated Safety Instrumented Functions (SIFs) existing or proposed.

6. Consequence Analysis

The consequences of potential hazards are fully modelled and analysed using technical tools such as DNV PHAST and Shell FRED. This can consider flammable effects such as jet and pool fires, Vapour Cloud Explosions (VCEs) and Boiling Liquid Expanding Vapour Explosions (BLEVEs) as well as toxic effects if a sour field is being studied.

7. Event Tree Analysis (ETA)

Event trees are 'bottom-up' analytical tree diagrams that determine the overall likelihood of a consequence. The event trees start with an initial hazard frequency, after which conditional modifiers such as ignition, etc. are applied and an overall frequency is calculated.

Results from the consequence modelling are used as part of the analysis to determine the number of potential fatalities from a particular hazardous event (e.g. flash fire).

8. Risk Assessment

These consequences are combined with the frequencies determined from FTA in the final risk assessment stage which considers factors such as probability of ignition, occupancy and leak frequencies to calculate an overall Individual Risk Per Annum, which is compared with the particular corporate risk criteria. Additional deliverables may include System Narrative documents for implementing SIFs and Lifecycle Cost (LCC) studies to compare the financial costs of several methods of risk reduction.

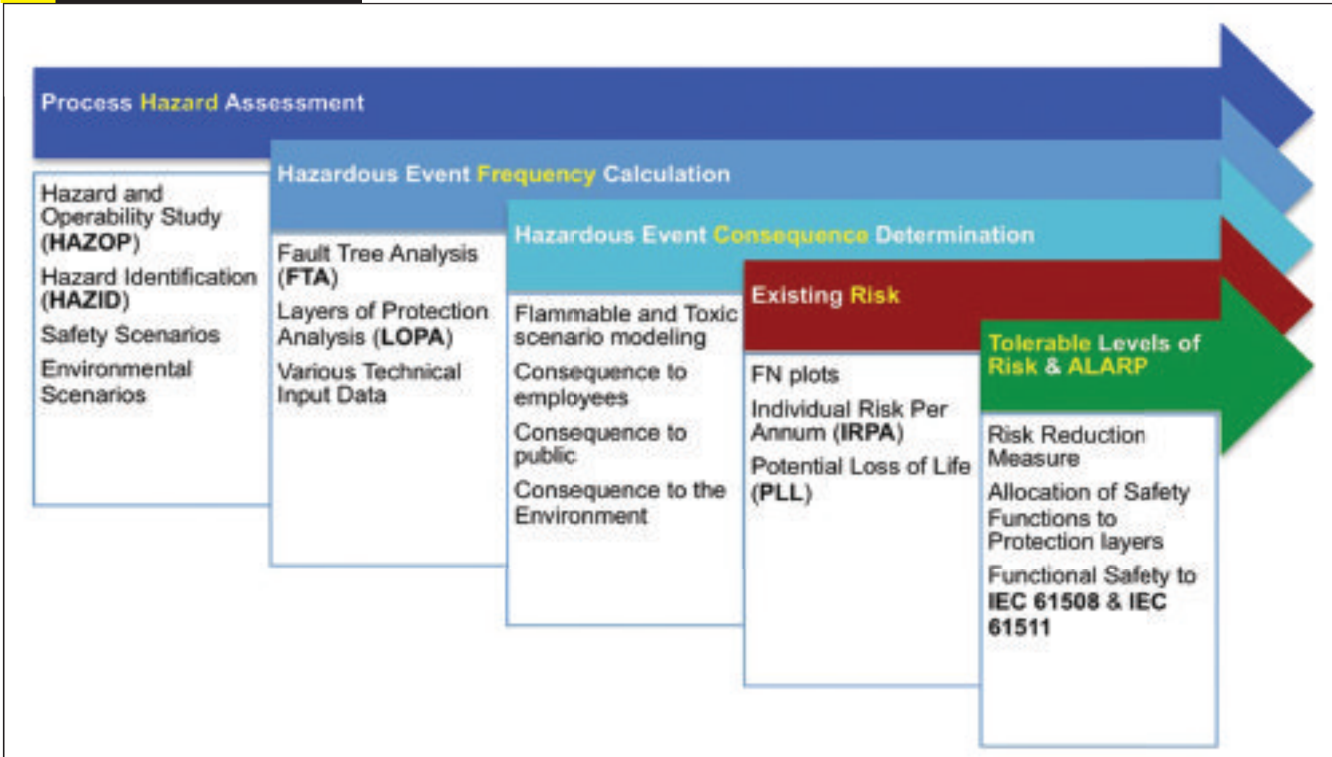

Figure 2. Technical Delivery

Risk Assessment

The risk calculations are carried out using the intermediate event frequencies from the ETA, the results from the consequence modelling and the probability of a fatality as a result of the hazardous release and its effects. The following sub-sections summarise the methodology and calculations that are carried out.

Potential Loss of Life (PLL)

PLL is defined as the level of risk (potential fatality) experienced by a group of people exposed to a hazard during a given year of plant operation. PLL is dependent on the number of people present in each group.

The ETA gives the frequencies from a list (n) of potential fatal accidents (Fi), and the consequence analysis calculates the number of fatalities for each of the fatal accidents (Ni). The PLL for each location is calculated by using the following equation:

$$PLL = \sum_{i=1}^{n} F_i \times N_i$$

In the above calculation Fi is taken as the impact frequencies determined from the ETA and other conditional modifiers, including occupancy percentage, weather category percentage and wind direction factor that can potentially cause risk. Ni is determined on the basis of consequence results, maximum number of personnel on site, site area and probability of a fatality.

Individual Risk per Annum

IRPA is the risk experienced by a single individual in a year. For offshore facilities that are generally unmanned, the IRPA and PLL have the following relationship:

$$PLL = IRPA \times P_N$$

Where; PN is the maximum number of people that may be present at a given location.

F-N Plots

F-N Plots or Curves, i.e. graphs relating the cumulative frequency per year of causing N or more fatalities. F to N are plotted for incidents such as overpressure scenarios, leaks and a combination of both in order to assess the risk and compare it with client's corporate risk criteria, in particular the maximum tolerable risk target.

It is evident that a customised approach produces a more realistic calculation of risk, thus better suits complex facilities where the cost of implementing conservative safety functions can be significant and therefore relates to many of today's process installations around the world. ■

About the author

Amir H. Akhlaghi is Engineering Director at Functional Safety Consultancy Ltd and has over 10 years of experience in Reliability, Safety-Related Systems, Risk Assessment and Safety Design.

He is a Chartered Engineer (CEng) at the Engineering Council and the IET, a TÜV Certified Functional Safety Engineer and a Technis Certified Functional Safety and Reliability Engineer. Akhlaghi is also a member of the Safety and Reliability Society (MSaRS) and the IET (MIET).