

GETTING FULL VALUE FROM HAZOP: A PRACTICAL APPROACH TO THE ASSESSMENT OF RISKS IDENTIFIED DURING STUDIES ON PROCESS PLANTS

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ABSTRACT

Busy plant managers working under time and budget pressures may be aware of the HAZOP technique but doubtful if it is suitable to apply to an existing operation let alone deliver a payout on the time and expense involved. This paper summarises an approach to HAZOP studies on operating plant which has delivered positive benefit cost for relatively little additional effort over and above that required for conducting the HAZOP itself.

INTRODUCTION

In the conventional approach, HAZOP studies are conducted during plant design and recommendations are incorporated prior to approval for construction. However, many process plants have been in operation for some time and have either undergone modification for debottlenecking or missed the HAZOP process altogether. In these cases it can be advantageous to conduct a HAZOP prior to major turnaround so that any recommendations to improve performance or safety can be incorporated along with other inspection and maintenance work.

Although Hazard and Operability Analysis (HAZOP) is a well-recognised method for hazard identification (ref 1) and is widely used in Process Hazard Assessment it suffers from practical difficulties. The method is known for its demand for intensive involvement from senior technical personnel from operations, maintenance, safety and process or project engineering taking these staff away from their day to day duties for the duration of the study which may be several weeks for a complex facility. This can make HAZOP a time-consuming and expensive exercise.

IMPLEMENTATION OF HAZOP RECOMMENDATIONS

The benefit for conducting a HAZOP study comes when the study recommendations are implemented and this is easier given a strong linkage to management processes for safety improvement, energy efficiency and investment appraisal. Without such linkage, HAZOP can reduce to a largely paper exercise serving as token compliance with external regulation or corporate standards.

When HAZOP is conducted as part of the design activities in a plant, the implementation of recommendations can be undertaken as part of the contractors overall scope. For example if HAZOP is undertaken on the P&IDs after design review prior to approval for construction, each recommendation can be addressed by the contractor in a close out report. This report may conclude there are good reasons that the recommendation be set aside or may incorporate it into updates of the drawings or draft manuals as appropriate.

For a plant, which is in service, implementation requires some other mechanism. It is important to recognise that there needs to be some plan to address each HAZOP recommendation because the HAZOP remains on file as 'discoverable' evidence in the event of an incident leading to legal action. It would not go well for a management team, which was shown in court to have ignored a recommendation pointing out a hazard, which subsequently lead to injury or loss.

The key to planning implementation activities is a sound method of prioritising HAZOP recommendations to recognise high risks in need of prompt attention. Once prioritised, recommendations need to be implemented as appropriate through operator action, unscheduled maintenance or turnaround as indicated in Figure 1:

Action	Purpose	Category
Immediate plant shut down	Urgent critical repairs to mitigate very high risk	Emergency work
Precautionary operator action	Change to current operations to mitigate high risk	Changes to operating manual Revisions to operator training
Switch to standby equipment or use of bypass	Repairs or modifications to mitigate high risk	Unscheduled Maintenance
Use of planned turnaround	Repairs or modifications to mitigate medium risk	Scheduled maintenance

Figure 1: Relation between risk, urgency of action and category of action

Only in rare circumstances will an unacceptable risk be identified requiring immediate plant shutdown but such situations can occur.

The key requirements for the prioritisation method are that it should be reliable, practical, compatible with existing budgeting practices and cost effective to apply.

PRACTICAL APPROACH TO RISK PRIORITISATION

The output from a full recording HAZOP takes the form of a tabulated record of the discussion on each guideword - parameter combination. Where the discussion identifies a potential hazard that the team feels is not adequately addressed in the existing arrangements, a recommendation is made describing what the team feels is a practical and effective mitigation.

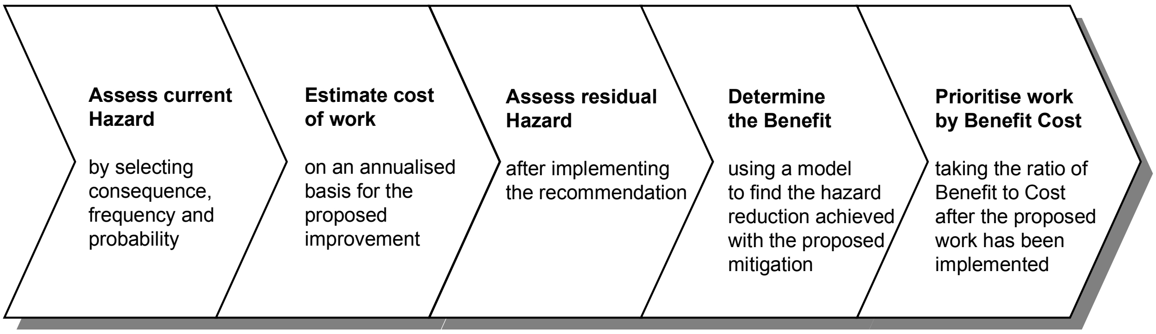

Figure 2: Sequence for prioritisation of HAZOP recommendation

To prioritise the recommendation the HAZOP team uses a matrix ranking approach in which the frequency of occurrence of the hazard, the probability the hazard will lead to a loss and the size of the loss are assessed. The assessment is carried out on the current situation and the situation after implementation of the recommendation. The cost of the mitigation is also estimated and the process is conducted stepwise in a workshop approach as illustrated in Figures 2 and 3.

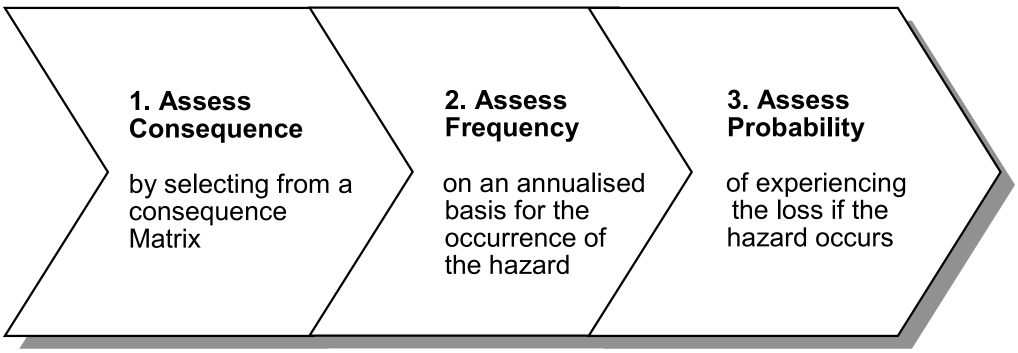

Figure 3: Sequence for assessment of hazard

The matrix approach is used for a number of categories of loss including:

- Property Loss
- Business Interruption
- Injury related losses to staff and third parties
- Environmental Liability
- Performance losses
- Losses of inventory

To facilitate the assessment by the HAZOP team members, recommendations are grouped by process issue and evaluated using Risk Register forms, which allow the implementation of the recommendation to be tracked. An illustration is shown in Figure 4.

Several difficulties with the workshop approach can be anticipated and some of these are addressed in the following questions.

IS GROUP ASSESSMENT ANY BETTER THAN GUESSING AT RANDOM?

The use of ranking matrices for risk prioritization has been practiced for some time (for example References 2 and 3). The HAZOP team carries out the assignment in a workshop session divided into groups who work together to assess each hazard using the ranking matrix. This process is facilitated by first grouping the recommendations into process issues which are categories of HAZOP recommendation which share a common operational or equipment aspect.

The extent to which two groups of experienced engineers working separately agree can be illustrated in Figure 5 which shows the assessment of 18 process issues which arose in the HAZOP of a 35 year old refinery plant.

In this assessment, five levels of risk were allocated to each of the 18 issues by two groups working independently. The diagram compares the actual differences between group assessment on the left and the pattern on the right, expected if the teams had chosen at random. The bars show the proportion of the process issues assessed at the same risk level by the two teams, the proportion differing by one risk level, two risk levels and so on up to 4 risk levels which represents complete disagreement on the ranking.

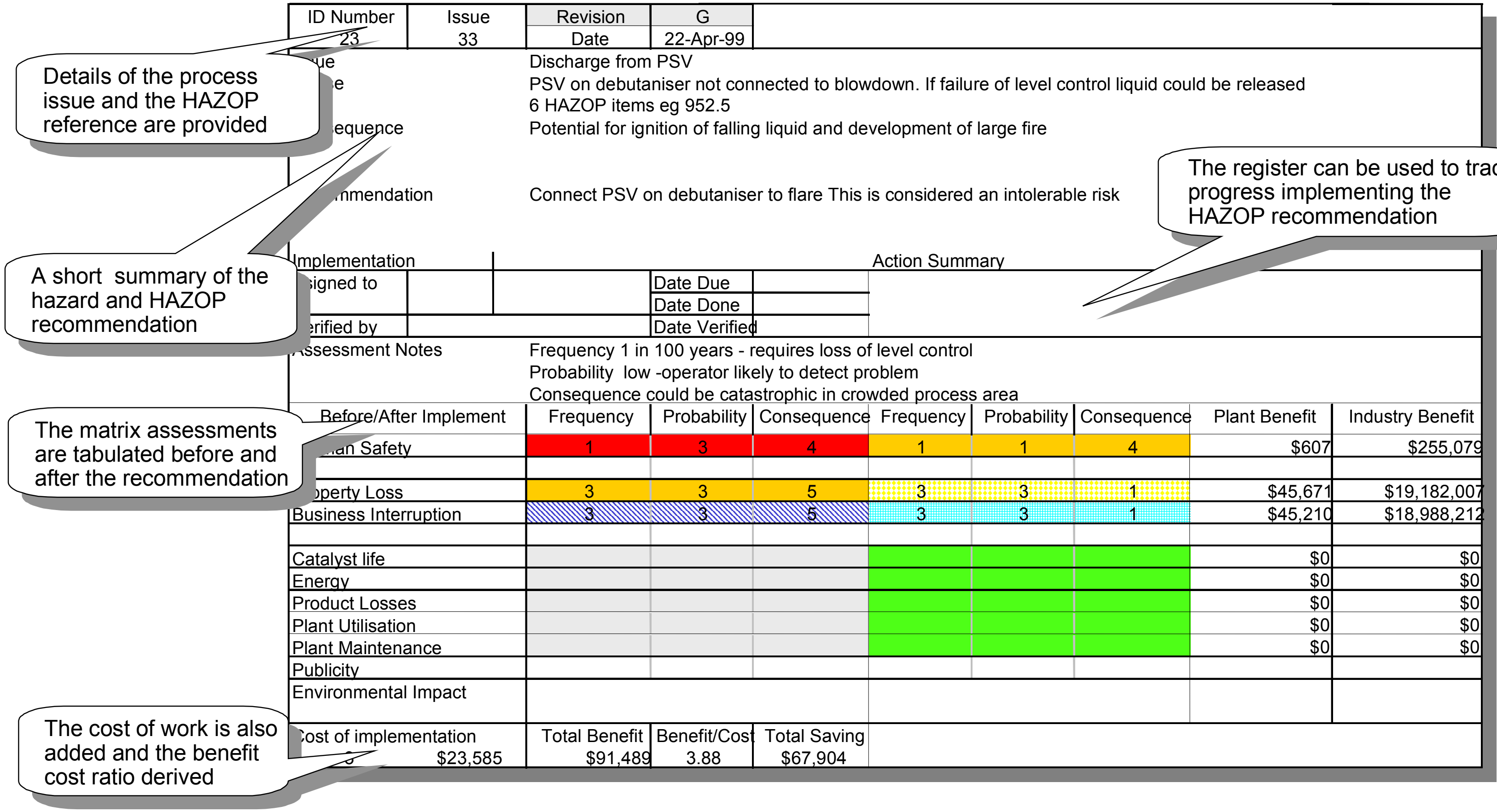

Figure 4: Risk Register page to facilitate prioritisation of recommendation

The figure shows that the teams had no complete disagreements and differed by 3 risk levels on about 15% of the issues. 85% of the process issues were assessed either at the same risk level or an adjacent level. 45% of the issues were assessed using the same level of risk. Had they been selecting at random they would have chosen only 20% the same. The result shows that group assessment produces better convergence than random selection and it allows the workshop facilitator to concentrate on the few areas of divergence and so make progress more effectively.

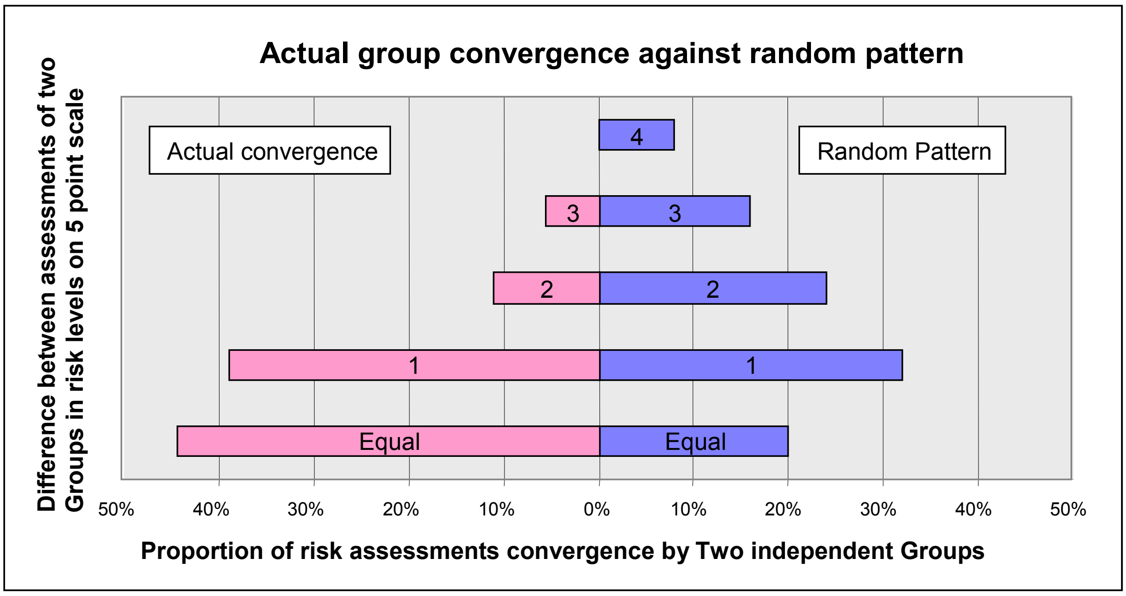

Figure 5: Performance of workshop groups against random selection

It is possible that the convergence of the group assessments is around the wrong risk level and this issue is tackled by the next question.

ARE RISK ASSESSMENTS BASED ON MATRIX ASSESSMENT REALISTIC?

One way to answer this question is to use industry loss histories to generate a Loss Expectation curve showing the size of loss that might occur in any time period for that category of plant plotted against the probability of its occurrence. The assessment of hazards by the HAZOP team using a ranking matrix can be used to simulate a Loss Profile for the plant in question which can be compared with the industry based Loss Expectation.

The illustration in Figure 6 shows three Loss Profiles. The red (dark) curve was derived from an accident database, which provided details of date of incidents and size of losses for a particular type of refinery plant. The brown (dashed) curve provides a similar set of data over a similar period for the same type of plant but this time from insurance claims. The similarity of the two curves drawn from completely different data sources offers some reassurance that the loss expectation is realistic.

On the same graph in yellow (light curve) is shown the industry loss expectation based on the assessment of the HAZOP recommendations of a modern plant in service six years. Firstly, the figure shows that the simulated loss profile is comparable in order of magnitude to the industry expectation and that, as would be expected, the modern plant benefiting from the recent know-how of the process licensor, has a loss expectation rather better than the average for plants of this type in the industry.

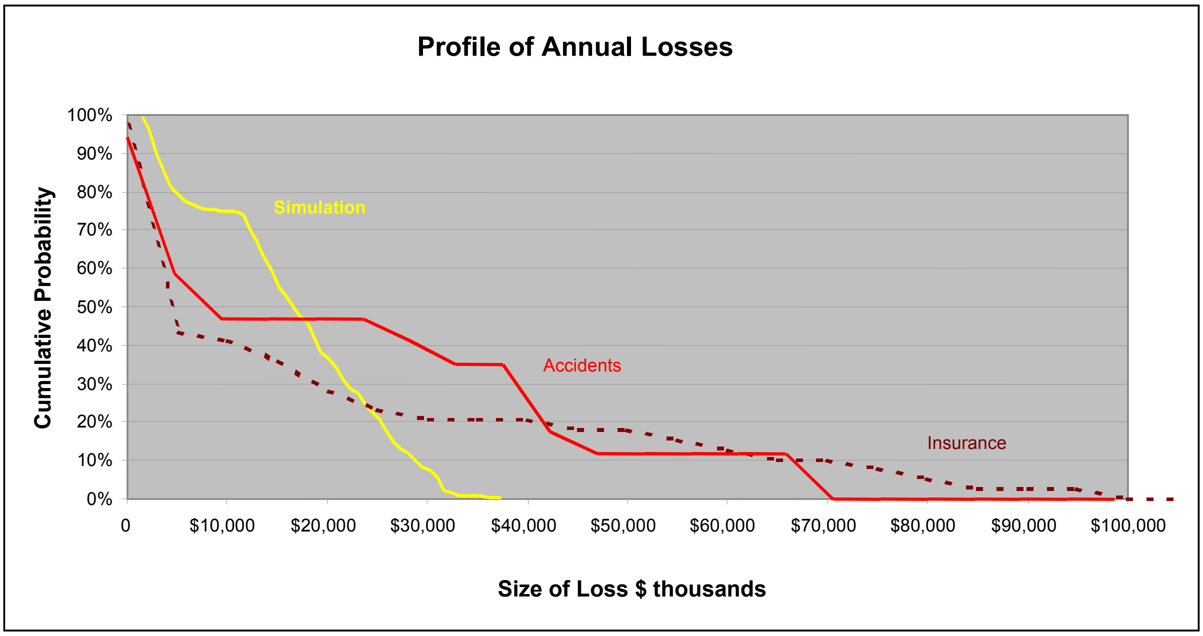

Figure 6: Loss profiles for a modern plant

A similar set of results can be compared, this time for a different plant type assessed by a different group in a different refinery. The curves are shown in Figure 7.

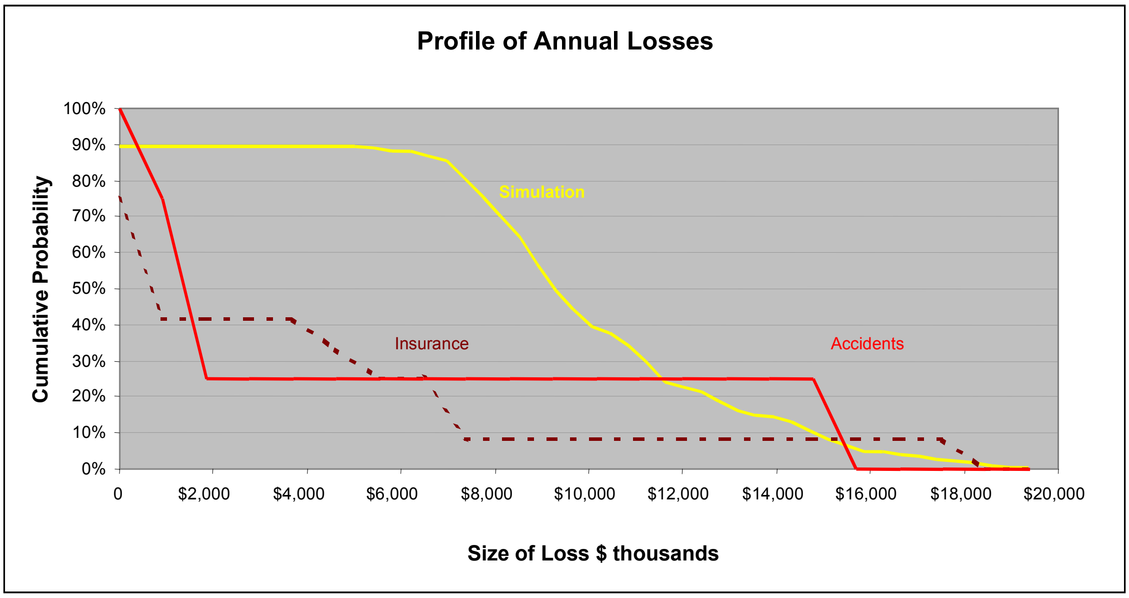

Figure 7: Loss profiles from an old plant

Again the similarity of insurance derived and accident database curves provide assurance that the profile of loss is realistic. The simulated curve derived from the HAZOP team assessment again covers a similar order of magnitude but shows losses on average rather higher than expected in the industry on average. For a plant built over 35 years ago this outcome is not unexpected.

These results suggest that different HAZOP teams can use the assessment approach to achieve realistic assessments of the hazards identified during HAZOP of their plants. In both cases the assessments were produced during an extra day and a half at the end of HAZOP studies which had taken two weeks so the approach can be seen as practical and not to cause undue extension of study time.

The Loss Profile graph can also be used to show the impact of recommendations. The following curve shows the simulated curve "after the recommendations" superimposed on the loss profiles for accidents and insurance data.

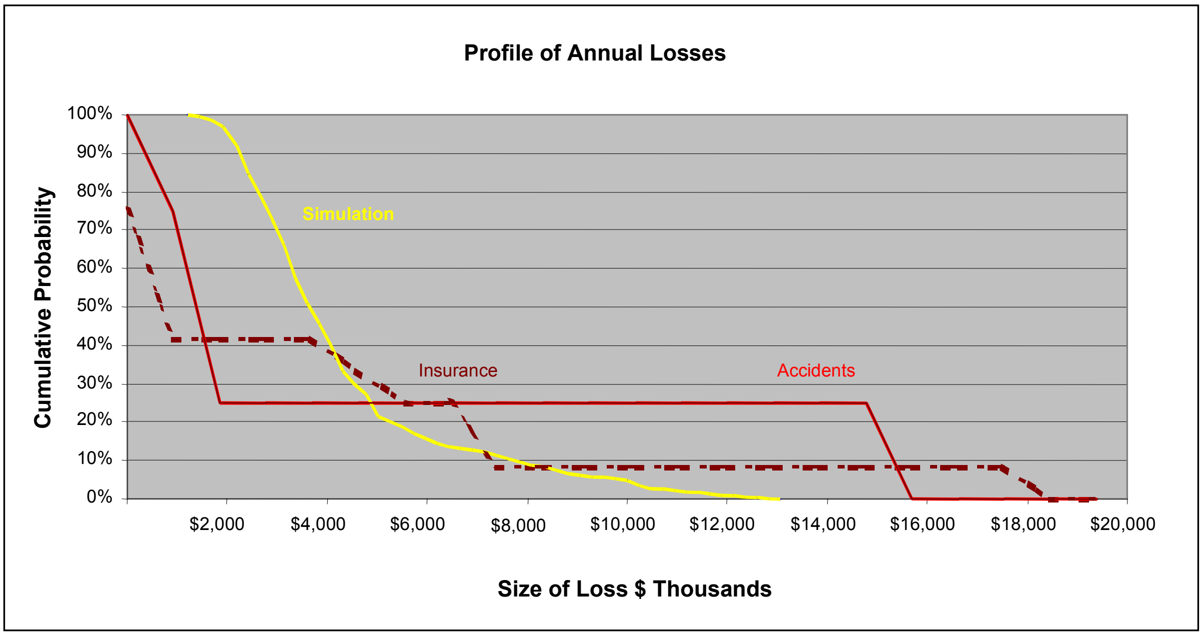

Figure 8: Loss profile for old plant after recommendations

Advocates of Quantified Risk Assessment (QRA), where specialists carry out detailed techniques such as fault tree analysis and consequence modeling, may feel that matrix assessment is too crude to give accurate results. This leads to the third question.

HOW CAN MATRIX ASSESSMENT PROVIDE AS RELIABLE RESULTS AS QRA?

To address this question, a number of moderate to severe risks identified in separate HAZOPs assessed separately by different HAZOP teams were examined by Fault Trees (to determine frequency) and consequence modeling (to determine effect distances for consequences such as pool fire, jet fire, dense cloud dispersion and explosion). Conventional criteria for 'dangerous dose' were used, including thermal radiation and explosion overpressure thresholds for fatal injury. The modeling was conducted using Arthur D Little software FaultEASE™ and Superchems™.

A correlation exercise was undertaken to compare the assessment of the HAZOP teams with the findings of the more systematic quantified risk analysis approach. The results for frequency assessment and consequence assessment are shown in Figures 8 and 9.

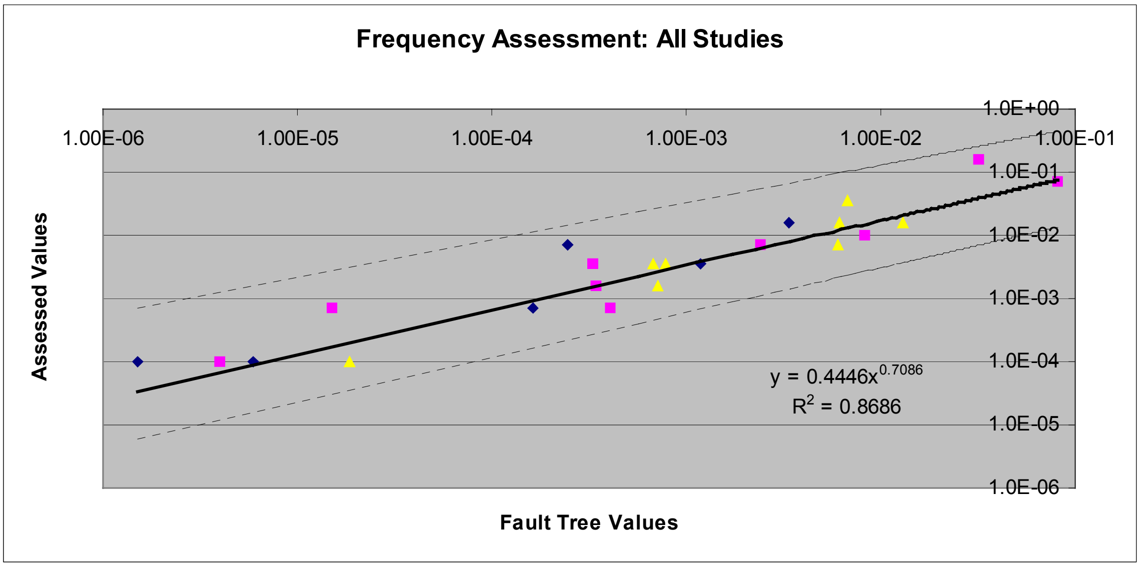

Figure 9: Frequency correlation

These graphs show:

- The data points as symbols. Three types are used, squares, diamonds and triangles representing assessments made by different HAZOP teams in different refineries.
- The best fit power correlation curve including the formula and value for R^2.
- The upper and lower ranges for the matrix assignments derived by taking the combination of lowest or highest values for frequency and probability from the ranges used by the teams.

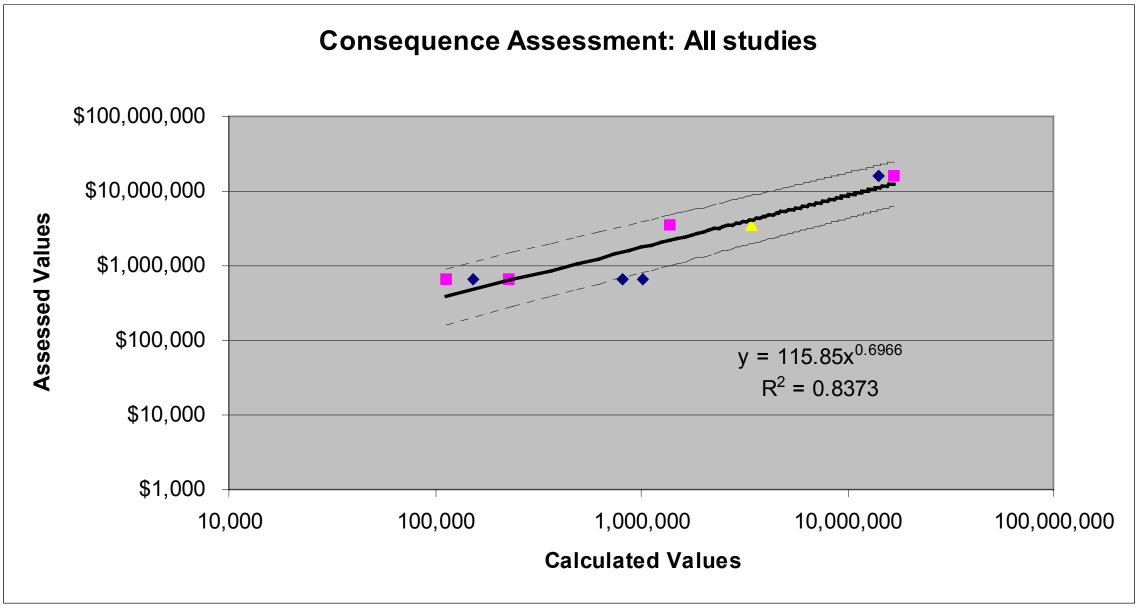

Figure 10: Consequence correlation

The result of the correlation exercises is to demonstrate that a reasonably strong relationship as indicated by values of R^2 over 0.8 exists between the results of detailed quantified risk assessment and the far more rapid matrix risk assessment.

Apart from other factors, the accuracy of the matrix assessment is limited by the range width of the matrices used for the assessment. As the correlation curves show all points lie in the band between the upper and lower matrix ranges used by the teams for their assessment.

DISCUSSION

The work reviewed in this paper shows that a workshop approach to assessment of hazards identified in HAZOP studies adds considerable value to the results of the work at comparatively little additional cost. Although the use of matrices for assessment seems crude and speculative, when used by groups of experienced engineers with appropriate facilitation, the method can produce consensus around realistic levels of risk. The results are shown to correlate reasonably with the results obtained with much more time consuming and expensive quantified risk analysis methods.

Coupling the approach with a Risk Register allows recommendations to be prioritised on a benefit-cost basis. In this way the economic benefit of risk avoidance or process improvement benefits offered by HAZOP recommendations can be assessed in relation to the costs of implementation and budgets available for activities such as unplanned maintenance or scheduled maintenance. When undertaken in advance of the planning for a major turnaround, the approach offers plant managers an effective way of identifying and prioritising plant modifications worth including in the scope of the turnaround contractor.

ACKNOWLEDGEMENT

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