Failure rate and equipment reliability data are an important input parameter in risk management. Whether it is to determine the individual risk from a major accident hazard facility or to determine the safety integrity level of instrumented protection systems, finding the appropriate data is often a challenging task for the designers, engineers, assessors and consultants.

A number of sources are available for data on incident rate, equipment failure rate and equipment reliability like the databases from the US Center for Chemical Process Safety (CCPS) and the UK’s Health and Safety Executive (HSE). Most of the databases are generic, based on a range of industries, a range of operating modes and failure modes. There are also database sources based on specific industrial sectors (like mining, offshore, chemical, etc.) or over a defined period of years or in a geographical location of interest, etc.

Some of the challenges faced by the risk assessors and design engineers in using the database are:

- To find the most appropriate database for the specific application.
- To understand the applicability of a certain database to the particular project of interest.
- The need to calibrate the available database to take account of specific conditions like geographical extremes or to meet the requirements of legislative criteria.

This poster will list such challenges and highlights the necessity to overcome the uncertainty in the use of failure rate data.

**INTRODUCTION**

Hazard, defined as the potential to cause harm, is associated to some extent with all activities and, for dangerous activities or those activities involving dangerous materials, the hazards will be high. In order to manage the hazard, one should identify the hazards and determine the extent of potential harm. Risk is the term used to represent the likelihood of the level of harm.

Assessing risk is an integral part of hazard management. The depth of risk assessment required is based on whether the hazard is minor or major, and is likely to change from qualitative, through semi-quantitative to quantitative risk assessment as the level of risk increases \([\text{HSE}^1]\). The likelihood estimation is carried out based on the device, equipment and/or system failure rate resulting in the incident. This poster highlights the significance of using the appropriate failure rate data in risk assessment and the difficulties often met in finding or deriving suitable information.

**SIGNIFICANCE OF THE USE OF APPROPRIATE DATA: AFFECTS THE RISK ESTIMATED**

Frequency estimation using failure rate data from different sources often derived from totally different data/sample sets could significantly affect the estimated risk. An event from gasket failure is taken as an example to illustrate the significance of appropriate data.

An illustration of risk estimated using incident rate from five independent data sources for a hazardous material release following gasket failure resulting in few serious injuries is given in the risk matrix (Table 1). The data sources and the failure rates are (A) Rasmussen report: 2.6E-2 per year, (B) UKAEA: 4.4E-3 per year, (C) Smith: 1.8E-4 per year, (D) Page & Nussey: 4.0E-5 per year and (E) UK Land Use Planning (5.0E-6 per year) \([\text{Mannan, HSE}^2]\).

Estimated risk ‘RA’ with failure rate data from Rasmussen report is predicted to be intolerable whereas estimated risk ‘RE’ using failure rate from UK HSE is predicted to be in acceptable region. Risk predicted from other data sources (RB, RC and RD) falls in the region between acceptable and intolerable.

This example demonstrates the shift of estimated risk is possible when failure rate data source is varied.

**USE OF FAILURE RATE DATA IN RISK ASSESSMENT**

The process involved in risk assessment and how the failure rate data is used in the assessment is illustrated in the Figure 1.
it is not often viable due to the high costs or practical difficulties.

The data available can be used either directly (based on the sample statistics) or can be inferred (based on the associated statistical distributions).

Some of the databases are collected from a particular data range for an intended field of use such as industry specific and application specific:

- **Industry specific database:** Information collected and maintained by a group of stakeholders of a particular industry. Examples: Offshore Reliability Data (OREDA), and Worldwide Offshore Accident Databank (WOAD).
- **Application specific database:** Data published for a particular application, often legislatively driven. Examples: Failure Rate and Event Data (FRED) published by the UK Health and Safety Executive (HSE2) for use within land use planning risk assessments, and Offshore Hydrocarbon Release Database also published by the HSE for use in offshore risk and integrity management.
- **Hazardous material specific data:** Example for corrosive materials.

### Table 1. Risk matrix

<table>
<thead>
<tr>
<th>Probability</th>
<th>RA</th>
<th>RB</th>
<th>RC, RD</th>
<th>RE</th>
<th>Tolerable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>($&gt;10^{-2}$ per year)</td>
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<tr>
<td>Improbable</td>
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<tr>
<td>($10^{-2} &lt; x &lt; 10^{-3}$ per year)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Unlikely</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>($10^{-3} &lt; x &lt; 10^{-5}$ per year)</td>
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<tr>
<td>Very unlikely</td>
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<tr>
<td>($10^{-5} &lt; x &lt; 10^{-6}$ per year)</td>
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<tr>
<td>Extremely unlikely</td>
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<td>($&lt;10^{-6}$ per year)</td>
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<tr>
<td>Severity / Frequency</td>
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<tr>
<td>Minor injury</td>
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<tr>
<td>Few serious injuries</td>
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<tr>
<td>Lost time incident</td>
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</tr>
<tr>
<td>Single or few fatalities, many injuries</td>
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<tr>
<td>Multiple fatalities</td>
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</tbody>
</table>

**Note:**
HAZID: Hazard Identification
FMEA: Failure Mode Effect Analysis
FTA: Fault Tree Analysis
LOPA: Layer of Protection Analysis

**Figure 1. Risk assessment process**
In addition, there are number of databases for determining the reliability of equipment, devices and systems such as:

- Center for Chemical Process Safety (CCPS) published guidelines for process equipment reliability data.
- Institute of Electrical and Electronics Engineers (IEEE) Std. 500, IEEE guide to the collection and presentation of electrical, electronic, sensing component, and mechanical equipment reliability data for nuclear-power generating stations.
- SINTEF Industrial Management’s reliability data for control and safety systems.
- Reliability Analysis Center, FMD-97, Failure mode/ Mechanism Distributions.
- Reliability Analysis Center, EPRD-97 Electronic parts reliability data.
- Sydvest, PDS Data Handbook.

**CHALLENGES**

Even though there are a number of sources of failure rate data, risk assessors often come across many challenges in using the data for risk assessment. Some of the challenges are given below:

- Finding the appropriate database: It is often difficult to find the database suitable for the specific application, for example:
  - Issues related to the statistical basis of the dataset, which may be unknown, like the sample set (limited population and sparse failure data), observation period (interval of time) for data collection (few days or many years), the time in service or the period/state of the project/plant (commissioning, operating or near decommissioning).
  - Issues related to the differences like the type of industry (for which the data was collected and used), and the geography (including climate conditions).

- Using the database: Interpreting the right information from a database and ensuring it is suitable for the intended purpose is repeatedly found to be dependent on the skill of the assessor. At times, lack of knowledge of the assumptions inherent in the dataset lead to incorrect calibration the data like taking benefit for something that has already been accounted for. Some of the related challenges include:
  - Data given in a range (lower and upper) or a number of values given for a failure rate of interest (mean, median, standard deviation, etc.).
  - The need to, and how to, calibrate the available database to take account of the conditions like geographical extremes or to meet the requirements of legislative criteria, etc.
  - Understand, interpret and apply under laid assumptions and take account of unknown factors.

- How to take account of the site specific factors: the maintenance practice, inspection regime, repair robustness, availability of standby and spares etc. vary from process to process, operator to operator and from location to location.

**Understanding the technicalities of the database:** Different databases use different criteria to classify and define the sources, failures, failure modes, observation period etc.

**FAILURE RATE DATA – DISCUSSION**

For a site with the same set of hazards, risk assessments carried out independently by different assessors inevitably produce different results [Louls]. This draws attention to the uncertainty in assessing risk. The differences arise as a result of using different failure rate data, assessment assumptions and consequence assessment methodologies. In an effort to overcome such differences, the Dutch Government has introduced a common approach by limiting the assessors and tool (Safeti-NL) through licensing [DNV2]. Some other efforts to appropriately use the failure rate data in risk assessment are given below:

- Guidance available specific to the database, for example OREDA estimator.
- Guide to finding and using reliability data for QRA – RADD [OGP].
- Method for combining failure rate data from various sources [H Schäibe].
- Process equipment reliability database (PRED) from CCPS of AIChe.

In general, while performing risk assessment the assessor needs to check the following to ensure that failure rate data are suitable for the purpose:

- Database is current (most up-to-date) and auditable.
- Database is suitable and relevant for the particular analysis application.
- Database is developed and maintained from an extensive population (large sample).

Further to this, the assessor should be aware of the limitation of the data source and where necessary alternatives should be sought. It is also important to understand the levels of uncertainty when using the results of QRA. Uncertainty analysis may be required based on the nature of the results of the QRA and how these are to be used. Sensitivity analysis shall be performed to identify which data or assumptions are contributing most to the risks. An analysis and judgement using upper and lower bound values (mainly for determining input parameters) is often used to demonstrate the conclusion and assumptions in the assessment [UKOOA]. As an example, for a QRA conclusion on a process plant at the initial design stage where the plot plan is not finalised, sensitivity analysis based on the length of associated pipe work shall be performed to demonstrate the acceptability of the assessment and finalise the design.
CONCLUSION
When performing risk assessment, it is important to recognise the limitations of the failure data sources. A number of data sources are available, but only relevant data suitable for the purpose should be used.

Simply acknowledging the fact that the failure data available are product specific or application specific will help designers and engineers recognize problems in their designs and any estimates of associated risk. Sensitivity checks on the uncertainties linked to the data help to gain a robust understanding of the results.

REFERENCES
DNV¹, WOAD – Worldwide Offshore Accident Databank, v5.0.1.
International Association of Oil & Gas Producers (OGP), Risk Assessment Data Directory (RADD).
Reliability Analysis Center, FMD-97, Failure mode/Mechanism Distributions, 1997, Rome, NY.

Note: “The opinions in this paper are those of the author and do not necessarily represent those of the employer.”