# CHAPTER 3
# RESEARCH METHODOLOGY

## 3.1 INTRODUCTION

The research methodology followed for this research work is given in the following parts. The part one deals with theoretical framework based on a thorough study of the theory of risk assessment techniques, the part included the scope and selecting case study facilities, the third part is carrying out analytical and modeling of data's for the selected facilities. The last part is development of a method which enhances the failure frequency.

## 3.2 STEPS OF METHODOLOGY

### 3.2.1 Part 1 Theoretical framework

There are numerous QRA models that are used by many countries and leading oil and gas companies throughout the world [40]. The CCPS-CPQRA model describes the methodology for quantitative risk analysis for chemical industries [40]. The Netherlands Government Centre for Prevention of Disaster (CPR) adopts a model for QRA, Physical effects and Probability assessment and provides guidelines. In India the IS standard 15656: 2006- code of practice is providing the guideline for hazard identification and risk analysis [9]. Failure Frequency Analysis is one of the main parts for assessing the risk. Historical or generic databases such as OREDA, EGIG, CCPS and HSE UK (About OSHCR on the HSE website, n.d.), were reviewed and analysed for natural gas facilities frequency data [15].

### 3.2.2 Part 2 Sources of Data

The industries using flammable gases such as LPG, LNG and hydrogen were selected for this study. From those, seven flammable gas facilities have been selected:

i. LPG storage facility at automobile ancillary at Tiruchirappalli, India;
ii. Hydrogen gaseous facility at power plant at Chennai, India;
iii. LPG storage facility at an auto mobile company at Hosur, India;
iv. Liquid hydrogen storage facility at Mahendragiri India;
v. LPG storage facility of High rise building at Muscat, Oman;
vi. Natural Gas storage facility at Oman;
vii. Natural Gas gathering station facility at Raslaffan, Qatar.

During the site visits, relevant data for risk assessment study were collected. The data such as process and instrumentation diagrams, process flow diagrams, inventories, equipment details and operating procedures and method statements. The operators, supervisors, maintenance team and safety professionals were consulted during this field study for clarifications related to operating parameters such as pressure, temperature, relief and shutdown systems and fire and safety protection systems.

### 3.2.3 Part 3 Analysis using statistical tools

The various statistical tools such as charts, line diagrams, pie charts & excel spread sheets are used in this study. Event Tree Analysis is used to find various hazardous event outcomes. Fault Trees are used to identify various causes that lead to top events. Software tools or models such as ALOHA and PHAST are used to establish various consequence modelling and its effects. Overall, the analysis consists of the following activities:

- Collection of data and analysis;
- Identifying the different incident scenarios;
- Physical effects modelling of incident scenarios;
- Frequency estimation;
- Consequence & Effects modelling;
- Estimation of risk.

### 3.2.4 Part 4 Generation of failure data

Establish a methodology to generate failure data for equipment pertinent to the LPG, LNG and Hydrogen industries. The failure data of equipment and components are established based on generic or historical database. However, it must be noted that these databases have limited data and do not have failure frequency data for all types of equipment.

The Parts Count Approach Method (PCAM) is applied for natural gas gathering stations and pipeline networks to establish total failure frequency of the facility. While the Bayesian approach is a statistical tool used by many applications to predict failures, it takes the existing generic or historic failure data and limited plant specific data combined to generate a synthesized failure data. These failure data are combined with PCAM method in order to update plant specific failure frequency. All the selected flammable facilities equipment and components or parts are taken into account in this study.

## 3.3 HAZID (HAZARD IDENTIFICATION) STUDY

The aim of Hazard Identification (HAZID) is to identify the hazards at an early stage of the plant life-cycle in order to eliminate or control them. The study followed a systematic methodology and used a checklist with a set of guide words to identify the various hazards and assess the influence on the facilities. The scope of the HAZID study involves present operations and future expansion of the plant. [40].

Table: 3.1 shows the guidewords to be used in the HAZID checklist. Indices are also used as a measure of the degree of hazard identification in various projects. Broadly, the indices are obtained based on the number of hazards identified and assessed in appropriate studies and projects.

Each category of hazard is further subdivided based on a set of further guide words to identify the hazard in the plant. For example, a typical subcategory hazards for external and environmental category are given in Figure 3.1.

*Table 3.1 Guide words*

| Sections | Category |
|---|---|
| External and environmental hazard | Natural environment |
| | Man-made |
| | Effect of plant to surrounding |
| | Infrastructure |
| | Environmental damage |
| | Control methods |
| Facility hazards | Fire and explosion |
| | Process hazards |
| | Utility hazards |
| | Maintenance Hazards<br>Construction hazards<br>Existing Hazards |
| Health Hazards | Health hazards |
| Project implementation issues | Hazard Management methods |
| | Contingency Plan |
| | Competency |
| | Contracting plan |

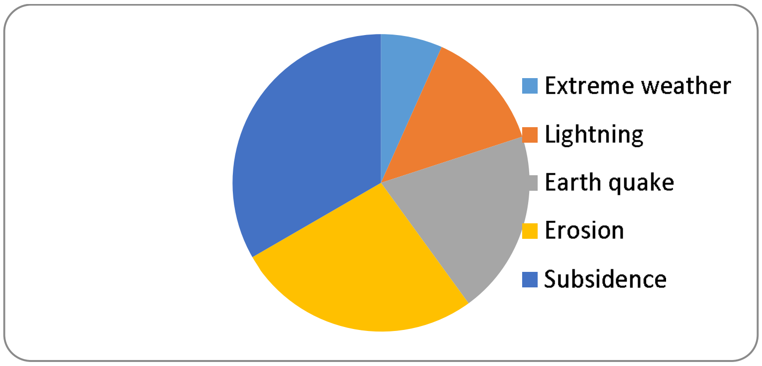


***Figure 3.1 Guidewords subcategory for external & environmental category hazards***

Each category and its subcategory of hazards is given with guidewords at **Appendix 1** as a check list.

This check list incorporated guidewords with category of hazards, so this combination is used to identify more comprehensive hazards in the facilities. Moreover it includes planning for operational hazard study requirement such as HAZOP, SAFOP and identify the requirement for further quantitative assessment.

## 3.4 HAZOP (HAZARD AND OPERABILITY) STUDY

HAZOP is an abbreviation for Hazard and Operability study. This study analyses the Oil and Gas process plant through rigorous processes [50]. ICI in the UK developed this standardised approach to analyses the process hazards associated with basic operations of the plant. It is defined as:

"The application of a formal systematic critical examination to the process and engineering intentions of new or modified facilities to assess the hazard potential or mal-operation or malfunction of individual items of equipment and the consequential effects on the facility as a whole".

It is used to identify deviations from the design intent that could lead to any hazards or operability problems, and to define any actions necessary to eliminate or mitigate those deviations. The HAZOP studies [60] are included from the original ICI method with required actions. These days, computerised methods for HAZOP study work sheets are employed for analysis.

The main objectives of the HAZOP study are:

- Identify potential hazards related to the system;
- Identify deviations from the design intent;
- Determine the operability of each facility as designed;
- Suggest recommendations to eliminate or mitigate the hazards;
- Appropriately simplify or improve design and the operations.

For this HAZOP study, a combination of guidewords and process parameters has been used to review the process and instrumentation diagram of the selected facility. The selected plant is divided into nodes as per the process flow diagram. Each node's intended function is defined and with the set of guidewords and process parameters applied the deviation and consequences of those deviations are assessed. If the existing protection systems have taken care of the consequences, then any additional measures to be provided are established. According to process data, technical information, process and instrumentation diagrams, material balance sheets, process parameters, instrumentation diagrams, site plans and line arrangements, a list of safety valves are to be kept ready before the start of the study [50].

### 3.4.1 HAZOP PRE-CONCESSIONS

The following are the pre-concessions followed during this study:

- All equipment are well designed, manufactured and properly inspected;
- Only single failure results are noted – no double jeopardy;
- Inadvertent closure/opening of manual valves are not considered;
- Natural Calamities such as falling of items from space, are not considered;
- Plant is well maintained and operated in accordance with acceptable standards;

- Failure of instrument gauges and valves are not considered i.e. fail closed valve will not fail open;
- Equipment catastrophes are not considered.

### 3.4.2 HAZOP TEAM

A multidisciplinary team is essential for this brainstorming HAZOP study. This is because the system is analysed for various types of deviation and how the safety and fire protection, instrumentation and mechanical and electrical systems operate and function to manage the hazardous situation or condition. The team members have experience and understanding in their respective engineering field such as process design, instrumentation and control, mechanical, project and operations. In this study a plant operator, foreman, supervisor, plant operation engineer, control room operator, safety engineer and construction engineer are part of the HAZOP study team. The process parameter guide words used for this HAZOP study of a Natural Gas Pipeline System is listed in Table 3.2 and the guide word deviations are mentioned in Table.3.3.

***Table 3.2: Process parameter***

| S.No | Description |
|---|---|
| 1 | Pressure |
| 2 | Temperature |
| 3 | Flow |
| 4 | Level |
| 5 | Composition |
| 6 | Phase |
| 7 | Operability |

*Table 3.3: Process parameter with Guide word*

| Word | Meaning |
|---|---|
| None | No flow at all |
| More of | More of flow, temp, pressure etc. |
| Less of | Less of flow, temp, pressure etc. |
| Part of | System composition different |
| More than | More thing present |
| Other | other than normal operation |
| Reverse | Opposite of what is to be |

### 3.4.3 BRIEF DESCRIPTION CASE STUDY FOR HAZOP

An example of natural gas (associated gas from well and flash gas from compressor) produced at the production station is compressed by a compressor and pumped into the export gas pipeline. During the process the gas is dehydrated by a dehydration unit and dew directed to a refrigeration unit. One sour gas pipeline exports this gas from the pumping station to the gathering station.

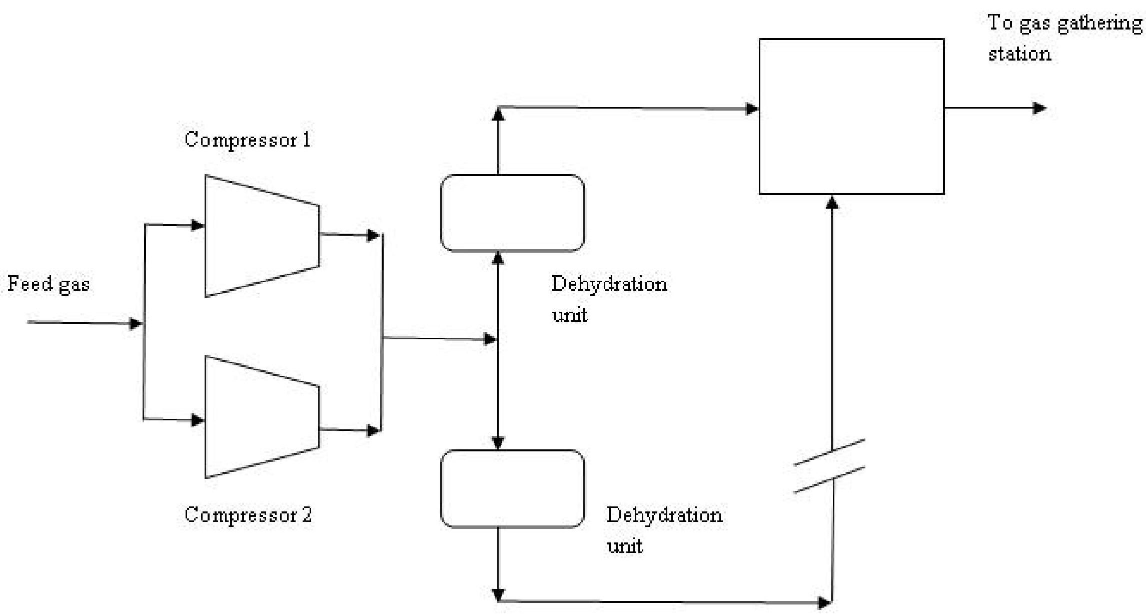


**Figure 3.2: Typical Flow diagram of Natural Gas production and pipeline system**

The HAZOP study was conducted based on the drawings provided for the natural gas compression and pipeline system. The findings were based on the design 'as is'. A number of changes have been identified for the improvement of the system and these should be incorporated.

The following are the key HAZOP recommendations based on the study:

1. Permanent access platforms shall be provided for the early tie-in valves wherever required;
2. An additional isolation valve with a spectacle blind shall be provided (for high sour service) for demolishing the redundant lines;
3. Appropriate Piping material specification shall be identified for all early tie-in provisions including high sour service;
4. Valve tag numbers shall be provided for all newly added early tie-in isolation valves which are of greater than 5" size.

**Table 3.4: HAZOP Worksheet Recommendations**

| HAZOP Node / Action No | Action Description | Action Party | Priority Level |
|---|---|---|---|
| 2A | Valve tag number to be provided for 3" and above sizes. | Design con. | 3 |
| 3A | Ensure that the MOC is adequate for high sour service | Design con. | 2 |

By implementing these recommendations and suggestions from the HAZOP hazard log action sheets, the risk of the natural gas compression and pumping system can be considerably reduced. The safe operation of the natural gas station and export pipeline will depend on the final design and a review of the revised system would be required in order to ascertain the changes are in order.

A typical HAZOP worksheet which is used for identification of operational hazards are enclosed in Appendix **2.**

## 3.5 LIMITATIONS OF HAZID / HAZOP TECHNIQUES

HAZID process is an important part of risk management. The study may discard some scenarios because they are extremely unlikely and of low consequence. Incomplete and inaccurate facility descriptions may lead to many mistakes and failure, or generate many actions and therefore lose credibility [87]. The HAZOP study [8] has numerous inherent weaknesses in the system. But understanding and having knowledge about the weaknesses enable the study team to compensate. This study can be [50] easily followed by people who are willing to use this technique to improve the performance of the plant and comply with the legal requirements.

The technique enhances and stimulates the imaginations of designers, engineers and operators in a systematic way so that they can identify the potential hazards in a design or modification. The HAZOP methodology is a powerful tool for identifying hazards and improves suggestions intended to reduce the risk level in the plant. The main feature of a HAZOP study is the "Examination Session" during which a multi-disciplinary team, using a structured approach, systematically examines all the relevant parts of a design. The continuous emphasis is on safety consciousness [62] and awareness among employer and employee which is vital for an organisation.

It is worth remembering that a HAZOP study [60] is not a simple application that assures a safe plant and operations on its own. It is always necessary before the study begins to establish scope, risk acceptance criteria, and expected results. The Heuristic Approach, [8] team brainstorming (asking for feedback about previous sessions), can provide false sense of security (not all important deviations are identified). So the complexity of a study is limited to the experience of the people involved. The HAZOP study takes more time than any other PHA study which could lead to team fatigue.

A HAZOP study may theoretically be a sound tool, but unfortunately in practice it has many weaknesses [8]. Weakness may also come from human inexperience, meaning of design intent, defined parameters, and generation of deviations and limitations of guidewords among other things. The HAZOP study is fully dependent on the knowledge and experience of the team participants. Some of the causes of a deviation may be unrealistic and derived consequences insignificant, and would therefore not be considered further.

A HAZOP methodology is straight forward to follow [50], however only through experience and engagement of multidisciplinary teams is it possible to understand the events responsible for deviations in order to validate the study [60]. The HAZOP study identifies hazardous situations [33] and initiating events, hence it provides opportunities. A HAZOP / HAZID study log must be properly recorded. Sometimes the wrong assignment of credit to existing safeguards can lead to ambiguity. All the actions/recommendations identified in the HAZOP study must be closed out in an appropriate timescale and this information must be fed through Hazard Log.

## 3.6 CONSEQUENCE ANALYSIS

Consequence is the degree of harm caused by any hazardous event scenario. Consequence modelling, also known as Physical Effects Modelling, is a technique in which computer based mathematical modelling is used to predict physical behavior under accident conditions, in order to make a quantitative estimation of risk. A range of models can be used, from simple formulations based upon test correlations, to complex numerical methods using CFD. Flammable gas facilities such as Natural Gas, LPG, LNG and Hydrogen are considered for this study. These gases are highly flammable and LNG & Natural Gas may contain considerable amounts of hydrogen sulphide which is toxic in nature. When these gases leak from containment, it can result in many consequences such as fire, explosion and toxic gas effects.

Figure in Appendix 3: shows the typical process flow diagram of natural gas compression and production system.

The following consequences are used by risk analysts depending on the scope of the flammable Oil and Gas facility:

Hydrocarbon-release models used to determine the leak rates from holes of different sizes;

Dispersion models used to determine the spread of flammable and toxic gas resulting from a leak;

Fire and associated radiation models for different types of fire e.g. pool fire, jet fire, flash fire, BLEVE fire ball, used to determine heat flux levels resulting from a fire at different locations in a facility;

Explosion overpressure models used to evaluate the pressures occurring as a result of ignition of a gas leak in a congested area. Results from an explosion-overpressure model and BLEVE overpressure models may be used in a dynamic structural program to assess the effect of an explosion on the structure.

LNG, LPG or Hydrogen are highly flammable gases which can result in fire and explosion in case of leaks during the unloading or loading activity or during transport from storage or pipelines. The various fire and explosion scenarios associated with liquefied flammable gases may result in jet fires, pool fires, and flash fires, Confined Vapour Cloud Explosion (CVCE), Unconfined Vapour Cloud Explosion (UVCE) and Boiling Liquid Expanding Vapour Cloud Explosion (BLEVE) [74].

### 3.6.1 CONSEQUENCE MODELS

Consequence Analysis is carried out based on the source model, and takes in to consideration how the materials are discharged e.g. from a pipeline or tank, and the type of failure. Then based on the source model, the fire and explosion outcomes are carried out based on the ignition probability. Usually the event trees are used to identify the different outcomes from any leakage scenarios. As per World Bank guidelines, flash fire, pool fire, UVCE and Toxic Cloud Dispersion are the models considered for consequence analysis in cross country pipelines carrying hydrocarbons [45].

The Jet Fire (immediate ignition), vapour cloud fire (flash fire), vapour cloud explosion (delayed ignition-explosion), toxic cloud (no-ignition) are the outcome cases of any leak of volatile, flammable liquids from a pipe. All these steps are covered by the modelling software during the analysis. Consequence analysis depends upon various parameters. The dominant parameters such as released volume, release rate, release direction, probability of ignition, time of ignition, and events associated with ignitions are considered. Thermal radiation and explosion over pressure are considered for assessing the damage criteria in the cross country pipeline carrying hydrocarbon risk assessment studies [45].

The hazard consequence assessment is based on consequence modelling to calculate the effects as follows:

a) Release of hazardous and toxic materials;

b) Gas dispersion;

c) Flame geometry;

d) Thermal intensity;

e) Overpressure magnitude;

f) Smoke or toxic cloud generation and engulfment;

g) Structural failure/damage;

h) Equipment damage;

I) Personnel evacuation;

### 3.6.2 EVENT TREE ANALYSIS

Event Tree Analysis attempts to describe the way an incident develops, based on different conditions at the facility that may result in different event outcomes. Various hazardous outcomes are discussed in the previous sections of this chapter such as Jet Fire, Pool Fire, UVCE and BLEVE, to name a few. However these outcomes depend on many factors such as availability of ignition source, weather pattern, wind direction and availability and reliability of leak detection and fire and safety protection systems in the facility.

During this research, event tree models were developed for different scenarios such as flammable gas leaks from storage tanks and pipelines. An example of accident scenario development for LPG bullet leakage and catastrophic failure and various outcomes were developed using event tree as shown in Figure 3.3.

The Event tree developed based on the LPG bullet results depend on many conditions such as catastrophic failure of the tank or not, immediate or delayed ignition, pool formed or not and a few more scenarios needed to be developed. The set of initiating events were generated based on the combination of leak sizes and inventories. Regarding LPG, if there is no ignition then the outcome case is considered safe as dispersion has no toxic effects. But at the same time Natural Gas or LNG facilities may contain significant quantities of $H_2S$ gas. So if there is no ignition then one of the outcome cases as a toxic effect has to be considered as a hazardous outcome. The timing of ignition is important because it could have affected the sequence of fire and explosion events. The possibility of isolating the leaks plays a role of limiting the amount of hydrocarbons released. So leak detection, how reliable and quick shutdown system is contributes to the inventory of the hydrocarbons for the organisation. If detection and/or isolation are delayed due to failures in leak detection and or shutdown systems then many event outcomes are possible.

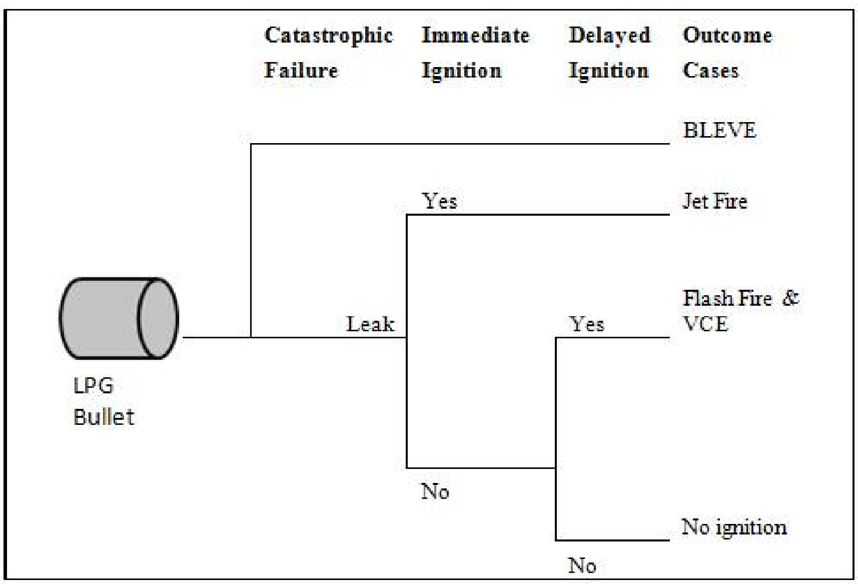


**Figure.3.3: Consequence analysis incident outcome of LPG storage tank failure**

Consequence also depends on prevailing weather conditions such as wind speed, direction, temperature and humidity during the time of release in the facility.

The conditions must be considered based on the locally available meteorological weather station records. For natural gas gathering stations and network risk assessments, the meteorological records from the station at Muscat, Oman were utilized Dispersion of released flammable gas depends on the roughness of the surrounding facility. Depending on location, the roughness values are chosen. This Natural Gas facility is located in what can be described as interior or covered terrain.

The magnitudes of each outcome case are evaluated by the PHAST software 6.5/ALOHA/FRED and their effect zones are derived. The hazards associated with Jet Fire and Flash Fire produce toxic gases and thermal radiation emissions in addition. [67]. Catastrophic rupture of vessel or pipe produces a massive release of LPG into atmosphere resulting in explosions such as BLEVE, if immediately ignited. If the ignition is delayed then results are CVCE or UVCE depending on the confinement. The consequence results and outputs are described in chapter 6 in detail for the selected case study.

### 3.7 SOFTWARE USED

LPG, Hydrogen gas, Liquid $H_2$ and Natural gas facilities were selected to carry out risk assessments for this work. As explained in the methodology, field surveys were conducted at these facilities and data required for performing a risk assessment was collected. Hazard identifications were performed for each facility and the potential hazardous accident scenarios were identified for further consequence analysis. Soft wares such as PHAST/ALOHA/FRED were used for deriving risk assessment models to find out the various consequences and their effects. Each case study consequence model is provided in detail.

The scope of work involved frequency analysis. So each facility's equipment, components, pipelines, piping, sizes and instrument connections were collected based on the processes, instrumentation diagrams and process flow diagrams. The description, accident scenarios, consequence model results and relevant charts and tables are provided for respective case studies.

### 3.8 INPUT DATA

The following are the input data which are collected during the site visits and are used during the modelling of consequence for each case study.

- Material
- Type of storage vessel
- Pressure
- Discharge Temperature
- Internal Pipe
- Pipeline Size
- Mass / Volume
- Air Temperature
- Relative Humidity
- Piping details
- Bund Size
- Volume Inventory of material to discharge
- Number of Excess Flow Valves
- Number of Non-Return Valves
- Number of Shut-Off Valves
- Pipe Diameter
- Pipeline Size
- Location
- Elevation
- Dispersion Concentration of Interest
- Flammable / Toxic
- Averaging time associated with Concentration
- Status of Bund

### 3.9 FAILURE FREQUENCY ANALYSIS IN QRA

Frequency estimation is the methodology used for estimation of the number of failure occurrences of a scenario which leads to loss of containment in a year, or an event per unit time. During hazard identification stage various hazards are identified which may lead to potential failure. In case of leakage in the flammable Oil and Gas facility or pipeline hazardous materials may be released into the atmosphere. This release may come from a small gasket failure in a flanged joint, a bleeding valve, inadvertently opening a valve, internal or external corrosion of a joint or from any other external interference. So it is important in the hazard identification stage to define the potential hazardous scenario that may lead to potential loss of containments. Once these potential scenarios are identified, then the next step is to estimate the failure frequencies for these scenarios.

### 3.9.1 GENERIC OR HISTORIC FREQUENCY DATA

Usually, the likelihood of basic event failure frequencies are taken from standard international failure databases. Many historical or generic databases are available internationally. Estimates may be obtained from generic historical data or from failure sequence models. What Risk Analysts consider depends upon the nature and scope of the study. Generic databases or company based failure databases can be used, but care must be taken when using these frequencies. In some conditions, generic databases may not have data or enough data for particular failure cases or the available data is not a relevant to those particular failure cases. In this situation risk analysts quantify the frequency based on Fault Tree Analysis. Sometimes generic databases may be available for particular facilities, for example, offshore failure data or pipeline failure data.

As an example, the OGP Risk Assessment Data Directory is a good source of generic data for valves, pipes, flanges and vessel failure frequencies. EGIG is another European database for selecting failure frequency of flammable gas pipeline transportation, and (EGIG) is used to determine the frequency rate of gas pipelines. In 1988 the offshore failure data base OREDA was established after the Piper Alpha Offshore Explosion. The HSE, UK published hydrocarbon released a database (HCR) for offshore Installations. It includes failure frequencies of process equipment collected from Oil and Gas operations in the North Sea. Even though it is specifically mentioned for offshore facilities, this data is considered to be the most appropriate for general quantitative risk assessment applications for Oil and Gas facilities. The data is based on individual incidents in detail and contains relatively large numbers of data records. Due to these reasons the HCR database is widely used in onshore Oil and Gas facilities risk assessment studies by risk analysts. The HSE, UK, collected the data in a systematic manner using forms and the Hydrocarbon Release Database (HCRD database) was generated.

The initiating event and enabling event likelihood estimations are calculated by historical data or subjective assessment by experts. The independent protective layers and probability of failure on demand for these layers are taken from guidelines. Mechanical interference, corrosion, construction defects, material error and human error are considered for external factors contributing to failure of cross country hydrocarbon pipelines [45].

Failure frequencies are another uncertain data used in risk assessment processes. Databases such as CCPS, OREDA and EGIG are used to select the failure rate for the particular study. But failures can be caused by design error, construction error, and vibration, corrosion, overheating and over-pressurizing [34]. Efforts to improve the failure data on on-shore process equipment by the HSE, UK are in progress with similar attempts by the CCPS, USA, gathering contributions from industries. LOPA is one of the tools that provides a consistent basis for judging whether there are sufficient independent protection layers to control risks [24].

Failure databases such as Rijmond (COVO.1982) study the HSE-UK and OREDA reliability datasets, while the Dutch Purple Book (RIVM, 2009) and CCPS (2000), Lees (Mannan, 2005) are used by QRA consultants and analysts for their studies. This produces sensible risk results even though they can lead to highly uncertain estimations. The data are not collected in a standard manner and some data are provided in high estimates [68]. These failure data are usually called generic or base frequency data.

### 3.10 VULNERABILITY CRITERIA

The fire and explosion models output and vulnerability assessment is based on over-pressure effects and radiation intensity [52]. Over-pressure and radiation intensity criteria are presented in the Table 3.5. Table 3.6 shows the over-pressure value and its effects in case of any confined or unconfined explosion and its effects on humans, structures and environment.

***Table 3.5: Radiation level criteria and its effects on human beings.***

| Radiation level ($kW/m^2$) | Physical Effect |
|---|---|
| 37.5 | Sufficient to cause damage to process equipment and death to humans. |
| 25 | Minimum energy required to ignite wood at indefinitely long exposure. |
| 12.5 | Minimum energy required to piloted ignition of wood, melting of plastic tubing, 50 % damage level. |
| 9.5 | Pain threshold reached after 8s; second degree burns after 20 seconds. |
| 4 | Sufficient to cause pain to personnel if unable to cover the body within 20 seconds; however blistering of the skin is likely; with no lethality. |
| 1.6 | Will cause no discomfort for long exposure. |

***Table.3.6: Over pressure criteria and its effects on human beings.***

| Pressure (PSI) | Damage effect by Blast |
|---|---|
| 1 | Partial demolition of houses, Made uninhabitable |

| | |
|---|---|
| 2 | Partial collapse of walls and Roofs of Houses |
| 3 | Steel frame buildings distorted and pulled away from foundation. |
| 4 | Cladding of light industrial buildings ruptured |
| 5 | Wooden utility poles snapped; tall hydraulic press in buildings slightly damaged. |
| 7 | Loaded train cars overturned. |
| 9 | Loaded train box cars demolished. |
| 10 | Probable total building destruction; heavy machine tools moved and badly damaged |
| 14.5-29 | Range for 1-99% fatalities among exposed populations due to direct blast effects. |

The objectives of the Hazard Identification study can only be achieved by proper close out of all actions and recommendations recorded in the Hazard Log. Where HAZOP is considered as a qualitative study, HAZAN is considered as a quantitative study. Frequency analysis is established for QRA study by many methods. FTA, ETA are used. But these techniques are combined together for assessing the risk [50]. Consequence analysis is carried out in order to find the severity due to various accident outcomes. ETA found that the outcomes such as jet fire, pool fire, explosion and toxic effect etc. various sophisticated software's were used to establish the consequences in QRA.

However, facilities in the Oil and Gas industry tend to use a HAZOP study with Fault Tree and Event Tree Analysis. The HAZOP with LOPA studies are used in assessing risk levels and which further helpful in making decision. In this work HAZID / HAZOP is used for hazard identification. The output consequence scenarios and corresponding failure frequency have also been identified.