LOPA – A TOOL FOR UNDERWRITING MAJOR CHEMICAL RISKS

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Abstract

Underwriting major chemical/ petrochemical risks has been the challenge for any insurer/ reinsurer. Particularly in the de-tariffed scenario decisions on accepting the risk and deciding the terms and conditions will be crucial for underwriters. Reinsurers who are affected by the underwriting decisions to a greater extent are looking for an easy, simple and objective method of risk evaluation technique which will enable them to decide the risk levels. The Layer of Protection Analysis (LOPA) which is used as the part of PLANOP (Progressive Loss of Containment Analysis – Optimising Prevention) can be used as a effective tool in the entire gamut of underwriting of chemical/ petrochemical risks. This technique invented by American Institute of Chemical Engineers, USA as Process Hazard Analysis technique can also be used as an effective underwriting tool. The author of this article has used this technique for analyzing the impact of risks for few hazardous industries like fertilizers, petrochemical premises which were approved by the statutory authorities and the industries concerned. This article briefly explains with example how LOPA can be used for underwriting of chemical/petrochemical risks.

Background

Insurance business has been experiencing rapid changes after the liberalization of the market in India. Every insurance portfolio is being de tariffed in phases. Particularly the decision of de-tariffing of property insurance or fire insurance has evinced interest among the insured and insurer.

From insured's point of view chemical/ petrochemical complex is unique considering the nature of hazardous materials handled, the technology adopted for operations and the level of protection measures employed by it. There are complaints of the anomalies of tariff in the existing All India Fire Tariff which rates the insured based only on the type of occupancy. The uniqueness of the risk pertaining to the insured's activities, the risk control measures adopted, possible consequences and frequencies of such occurrences are not taken in to account. The insured are looking for merit based rating instead of general market driven premium calculations which do justice for the risk control measures.

On the other hand the insurers and reinsurers are also affected by the generalized industry based tariff structure. It is very difficult to evaluate the risks in chemical and petrochemical manufacturing and storage facilities and to treat them equally. Their decisions in underwriting such properties prove to be crucial when the assets and business interruptions are of high value. The risk assessment needs to be accurate and be accepted by all those concerned.

What is LOPA?

It is a simplified risk assessment method introduced by Centre for Chemical Process Safety of American Institute of Chemical Engineers, USA[1]. The LOPA method was originally developed in the context of defining Safety Integrity Levels (SILs) for electronic/electronic/programmable electronic safety related systems. Subsequently LOPA has found more widespread use as a risk assessment technique.

This method utilizes the hazardous events, event severity, initiating causes and initiating likelihood data developed during HAZOP. It evaluates risks by orders of magnitude of the selected accident scenarios and builds on the information developed in qualitative hazard evaluation e.g. PHA.

LOPA Process

LOPA is based on the assessment of single event- consequence scenarios. A scenario consists of an initiating event and a consequence. Though multiple initiating events can lead to same consequence, all these initiating events must be used to develop scenarios for subsequent assessment. A typical LOPA scenario chain is indicated as figure 1 for understanding:

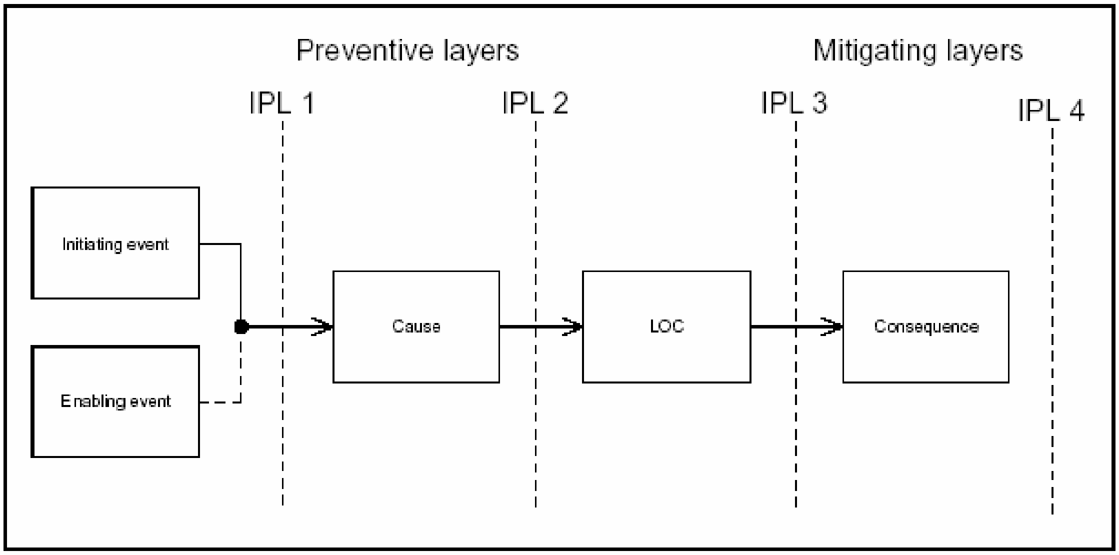

Fig 1: LOPA scenario

For understanding of the above terminology we will take an example of LPG storage area premises. The bullet is designed as per standards and the area is isolated from rest of the factory premises. About 10,000 Kg (22000 pounds) of LPG is stored inside the bullet.

Event – Initiating and Enabling

An event is an occurrence to an accident scenario. The initiating event is the event that starts the chain of events leading to the undesired consequence. An enabling event or enabling condition is an event or condition that is required for the initiating event to unleash a scenario. Enabling events are neither failures nor protection layers. They are expressed as probabilities. For example release of LPG from the bullet can be considered as an event. In this case LPG leak from the cracked pipeline can be the initiating event. Presence of Ignition source in the area can be the enabling condition. Initiating events could be external events like earthquake, wind storm, flood etc, failures of equipment like rupture or leak of vessel, pipeline etc. or human failures.

Cause

Condition or state resulting from the events that allowed the Loss of Containment to occur. The pipeline material failure is the cause of LPG leak.

Loss of Containment (LOC)

Loss of containment is defined as the top event in a scenario, that one aims to prevent from occurring. Fire or explosion due to LPG release is the loss of containment.

Consequence

The consequence or effect is defined as the undesired outcome of an accident scenario. Consequences are expressed in terms of material damage, environmental pollution, injuries, fatalities etc. In our example both the material damage and injury due to hydrocarbon fire are the consequences.

Independent Protective Layers (IPL)

Independent Protective Layers are devices, systems, or actions that are capable of preventing a scenario from proceeding to an undesired consequence and all these layers are independent from one another so that any one failure of the layer will not affect the functioning of the other layers. The layers can be either preventive in nature by avoiding an occurrence of the scenario or mitigating by minimizing the effects of consequences. Examples for preventive independent protective layers are:

- Process Design
- Basic Process Control System (BPCS)
- Alarms and associated operator actions
- Physical protection like relief devices, dyke, Safety Intrumented Systems (SIS) etc.

Post release physical protection like fire protection systems, plant and community emergency response etc can be considered as mitigating protective layers. Provision of Pressure cum Vacuum Relief Valve or Safety Relief Valve on the tank/ container can be one of the Independent Protective Layer.

Methodology

The analytical LOPA method consists of a number of steps viz establishing a consequence criteria, identification of accident scenarios and their frequency of occurrence, identification of IPLs, estimation of risk and review of existing risk control measures based on the acceptance criteria. (Refer figure 1)

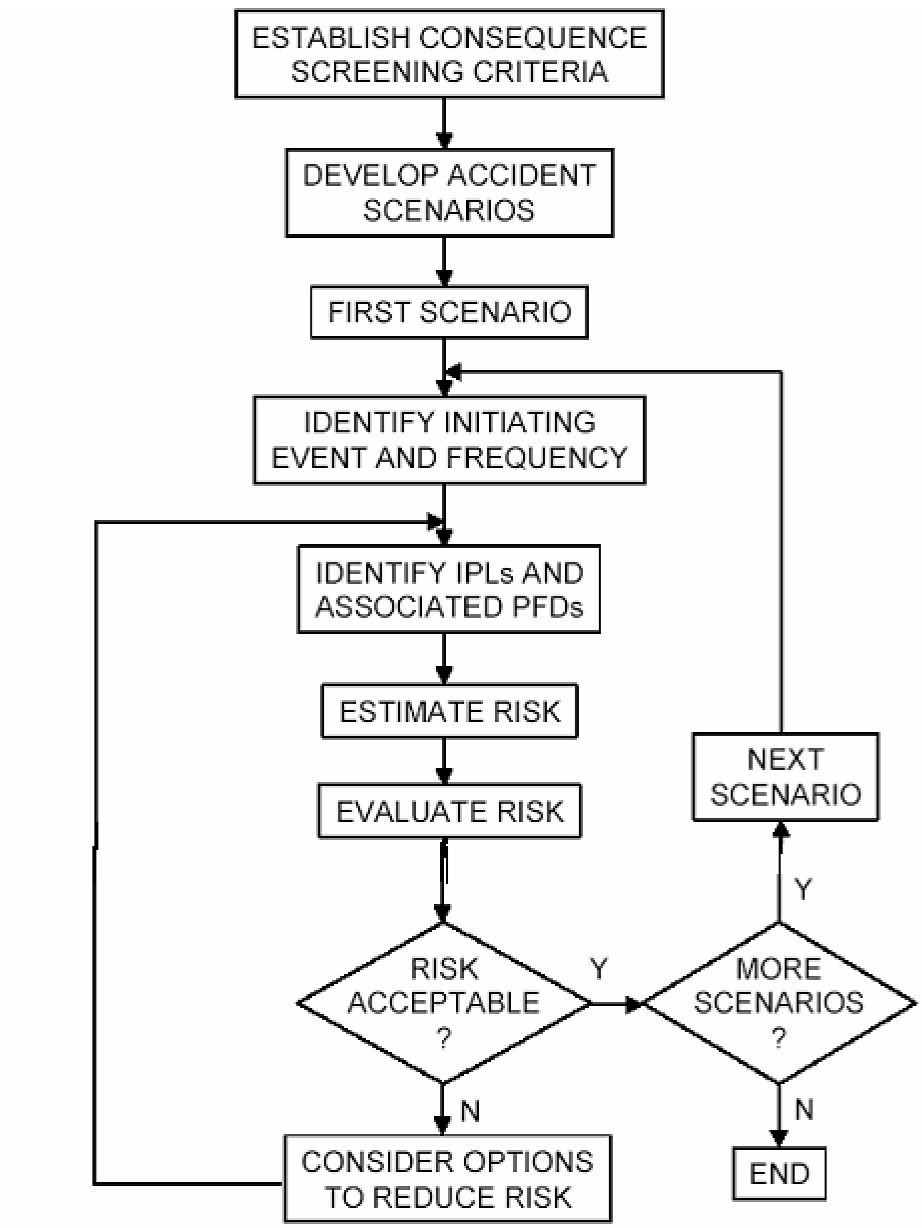

Fig 1: Steps involved in LOPA process

Risk assessment for Insurance Underwriting

Risk assessment by using LOPA can be carried out for various purposes. Presently it is used for assessing the risk levels by means of evaluating the adequacy of layers of protection to verify whether the residual risk is with in the statutory or standard norms. Considering the scope of the article let us limit our discussion with respect to using LOPA technique for underwriting purposes. For those who are interested in knowing more about this technique may refer the literature mentioned under the references or contact the author by email at ***rameshbabuJ@cholams.murugappa.com***

The underwriter can select accident screening criteria based on his site visit and the type of coverage offered by him. For example for a reinsurer the line of protection, type of reinsurance coverage and excess limits may be guiding factors to select the accident screening criteria. In case of local insurer the scope of insurance coverage, compulsory and voluntary excess and statutory norms binding on insurance coverage can be considered as the basis.

Once the criteria is selected the insurance engineer/ risk management consultant appointed by the insurance company can carry out the site visit. During site visit he can inspect the premises and identify the physical hazards leading to accident scenarios meeting the criteria selected. The documents like Quantitative Risk Analysis (QRA) and Hazard and Operability Study (HAZOP) can be helpful in identifying the accident scenarios.

The crucial step of LOPA is evaluation process and the following criteria can be used for assessment of risks.

- Consequence class characteristics,
- Likelihood estimation

<u>Consequence class</u>

Consequence class characteristics are classified in different ways from three levels to five levels as chosen by the study team members. The basis for classification depends on local regulations and corporate safety and environment philosophy. Consequences are measured in terms of damage to people, property and environment. The extent of damage can be predicted by means of experimental values or simulated values available for the chemicals. The advantage of LOPA technique lies in the fact that it can be used even if no software simulation is available for quantification of consequences. To reduce the subjectivity, the guidelines for estimation of consequences have been developed by some experts based on the quantity of chemicals involved in the scenario. The guidelines suggested by Colin S. 'Chip' Howat Ph.D. are widely accepted for estimation purposes. (Refer table 1)

Release Characteristic \ Consequence Size	1- to 10-pound Release	10- to 100-pound Release	100- to 1,000-pound Release	1,000- to 10,000-pound Release	10,000- to 100,000-pound Release	>100,000-pound Release
Extremely toxic, above B.P.*	Category 3	Category 4	Category 5	Category 5	Category 5	Category 5
Extremely toxic, below B.P. or Highly toxic, above B.P.	Category 2	Category 3	Category 4	Category 5	Category 5	Category 5
Highly toxic, below B.P. or Flammable, above B.P.	Category 2	Category 2	Category 3	Category 4	Category 5	Category 5
Flammable, below B.P.	Category 1	Category 2	Category 2	Category 3	Category 4	Category 5
Combustible liquid	Category 1	Category 1	Category 1	Category 2	Category 2	Category 3

*B.P. = atmospheric boiling point

Consequence Characteristic \ Consequence Category	Spared or Nonessential Equipment	Plant Outage <1 Month	Plant Outage 1 to 3 Months	Plant Outage >3 Months	Vessel Rupture 3,000 to 10,000 gal 100 to 300 psig	Vessel Rupture >10,000 gal >300 psig
Mechanical damage to large main product plant	Category 2	Category 3	Category 4	Category 4	Category 4	Category 5
Mechanical damage to small by-product plant	Category 2	Category 2	Category 3	Category 4	Category 4	Category 5

Consequence Characteristic \ Consequence Cost (U.S. dollars)	$0 – $10,000	$10,000 – $100,000	$100,000 – $1,000,000	$1,000,000 – $10,000,000	> $10,000,000
Overall cost of event	Category 1	Category 2	Category 3	Category 4	Category 5

Table 1: Guidelines on consequence estimation

It may be noted that categories can be defined in terms of financial loss as shown in table 1. However the values stated in the table may vary based on the size and financial risk tolerance limits chosen by the organization. The category referred in the table 1 is defined in terms of effects on plant personnel, community and environment as shown in table 2.

Consequence class	**Plant personnel**	**Community**	**Environment**	**Financial**
1/2	No lost time	No hazard	No notification	Minimal equipment damage (<$100,000) &/ or no loss of production
3.	Single injury	Odour / noise	Permit violation	Some equipment damage (>100,000) &/ or minimal loss of production
4.	> 1 injury	One or more injuries	Serious offsite impact	Major damage to process area (>$1,000,000) &/or some loss of production
5.	Fatality	One or more severe injuries	Serious offsite impact	Major or total destruction of process area (>$10,000,000) &/ or significant loss of production

Table 2: Definition of categories of consequence

<u>Likelihood Estimation</u>

The frequency of initiating event is based on the past industry data, company experience or incident histories. If no data available, estimation can be made based on the subjective assessment of expert team. Some of the data used by the industry for various events have been published in the literature mentioned under references.

Then Independent Protective Layers available in the system to prevent occurrence of accident scenarios or mitigate the consequences need to be identified along with their Probability of Failure on Demand (PFD). In case of non- availability of specific PFD values the standard values given in the literatures can be taken as guidelines. The final residual risk measured in terms of consequence class and frequency. Let us continue with our example of LPG storage and use LOPA method for underwriting the LPG storage risk.

***<u>Accident Scenarios</u>* : Fire / Explosion due to LPG release**

Location: LPG storage area

Equipment: LPG bullet & associated pipelines

Sl. No.	Initiating event (IE)	Probability Per year f_{IE}	Enabling Event (EE)	Probability Per year f_{EE}	Protective Independent Protective Layers (IPL) Probable Failure on demand (PFD)				Mitigating IPL PFD	Consequence	
										Class X	Frequency Y
		F_1		**F_2**	**P_1**	**P2**	**P3**	**P4**	**P5**		**F1XF2XP1x P2xP3xP4X P5**
1	Pipeline leak	10^{-2}	Presence of ignition source in the area	10^{-2}	10^{-1}	10^{-1}	10^{-1}	10^{-1}	10^{-1}	**5**	**10^{-9}**

Table 2: LOPA underwriting sheet of LPG storage

Note:

<u>Protective Layers present</u>

P1 : Pipeline designed to withstand 1.5 times the maximum operating pressure
P2 : Safety Relief Valves are provided on pipeline
P3 : Periodic inspection and testing of pipeline is carried out
P4: LPG leak sensors are provided and maintained in good condition
P5: Fire hydrant system is provided to deal LPG fires
X : May lead to Category 5 scenario (refer table 1) for the prescribed LPG quantity

The final risk level of consequence category 5 and frequency of 10^{-9} can be plotted in the following risk acceptance- underwriting matrix. The basic acceptability criteria used in the matrix is based on the limits specified in the Netherlands statutes as India does not have similar statutes.

Frequency of consequence (/yr)	Consequence Category				
	Category 1	Category 2	Category 3	Category 4	Category 5
$10^{0} – 10^{-1}$					
$10^{-1} – 10^{-2}$					
$10^{-2} – 10^{-3}$					
$10^{-3} – 10^{-4}$					
$10^{-4} – 10^{-5}$					
$10^{-5} – 10^{-6}$					
$10^{-6} – 10^{-7}$					

Table 4: Risk acceptance- Underwriting matrix

Note:

1. **Legend interpretation**

	Under the risk at the rate less than the basic industry rate
	Underwrite the risk at the basic industry rate
	Underwrite the risk at twice the rate of basic industry rate
	Underwrite the risk only at the premium rate (3 times the basic industry rate)
	Underwrite the risk only at the very high premium rate (5 times the basic industry rate)
	Avoid underwriting the risks

2. All major accident scenarios can be identified and used for screening purposes.
3. In case of more than more than one scenario in a plant, major scenario should be taken for underwriting purposes.
4. The rates suggested are only indicative and underwriters may modify according to their risk acceptable limits and past experience. These rates need to be reviewed periodically.
5. The basic industry rate is arrived at based on the actuarial experience for each type of chemical/ petrochemical premises.

From the above matrix the insured will understand the clear basis for the premium rates charged and will motivate them to go in the additional layers of protection to improve the risk levels and minimize the premium outgo. The insurer also can choose his risk based on his acceptance limits. To conclude our example the LPG storage risk can be underwritten at the basic industry rate.

Benefits of LOPA method

- This method is applicable to all types of chemical and petrochemical units.
- It does not require any use of complicated software to assess the consequences.
- It is simpler than the existing dow index method used by Petrochemical tariff followed by the insurers
- Due credit is given to all independent protective layers and residual risk is identified objectively.
- It is a transparent tool making the insured to appreciate its objectivity and informs them about the scope for improvement wherever required thereby the possibility of reduction in the premium.
- It does not deal with loading or discount which normally lead to violation/ misunderstanding by operating personnel of insurance companies.

Conclusion

This technique has been popular in western countries as an effective tool for risk analysis purpose. Slowly its utility is being appreciated in Asian countries also. If insurers develop this technique after fine tuning the underwriting process will be more objective and satisfactory to both insured and insurer as well.

References

1. AIChE CCPS (2001). Layer of Protection Analysis - Simplified Process Risk Assessment.
2. Franks A P (2003). Lines of Defence / Layers of Protection Analysis in the COMAH Context.
3. Colin S. 'Chip' - Layer of Protection Analysis – A semi quantitative method between hazard identification and quantitative risk assessment
4. R.J.A. Kersten and W.A. Mak, TNO Prince Mauritius Laboratory, Netherlands- Explosion hazards of Ammonium Nitrate, How to assess the risks
5. www.primatech.com- FAQ Sheet – Layer of Protection Analysis
6. Arthur M Dowell & Dennis C Hendershot – Simplified Risk Analysis – LOPA
7. Anton A. Frederickson (2002)- The LOPA method

8. Paul Baybutt & Joel Haight – Analysis of Human Factors for Process Safety : Application of LOPA- HF to a fired furnace
9. Richard Gowland- Practical experience of applying Layer of Protection Analysis ofr Safety Instrumented Systems (SIS) to comply with IEC 61511
10. http://www.cholarisk.com J. Ramesh Babu: Layer of Protection Analysis – An effective tool in PHA

About the author

J. Ramesh Babu is a chemical engineer with post graduation qualification in Business Administration. He holds the diploma in industrial safety. He is an Associate of Insurance Institute of India and Associate of Institute of Risk Management, UK. He has the experience of over 19 years in operations and risk management consultancy. He has conducted studies in the area of fire safety, process safety, insurance planning, risk and reliability study for over two hundred and fifty occupancies including process industry located in India, Thailand and Kuwait. He has used LOPA technique for risk analysis for a variety of industries like Fertiliser industry, distilleries etc. in India. He has carried out a number of major fire investigations on behalf of insurance companies. He has conducted three hundred training programmes on various topics of risk management. He has presented papers in seminars held in India, Sri Lanka and Singapore. He is presently working as Deputy General Manager- Risk Services in Cholamandalam MS Risk Services Ltd., Chennai, India