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Approaches for Risk Assessment Method Selection Criteria

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Abstract

In safety engineering there are several risk assessment methods ranged from simple to complex, quantitative or qualitative and semi-quantitative. May be researchers or experts they need to answer the question: (which method we choose and why?). It may sometimes be necessary to employ more than one method of assessment. Two approached conducted the first approach discussed the selection of risk assessment method in consideration of availability of resources, uncertainty and factors influencing method selection. While the second approach discuss the selection criteria accordance of consequence assessment and frequency assessment. It found that the selection of methods affected mainly by environment under consideration. After this analysis it is suitable to conduct the risk assessment for the case study by using HAZOP as qualitative methodology and for quantitative FTA will be conducted. It is possible to mix the two approaches to form one model for selection process.

Keywords: risk assessment; selection; method; qualitative; quantitative.

1. Introduction

Since selecting an appropriate hazard evaluation technique is more an art than a science, there may be no “best” method for a particular application. The thought process behind selecting hazard evaluation techniques is complex, and a variety of factors can influence the decision-making process. [1] In safety engineering there are several risk assessment methods ranged from simple to complex, quantitative or qualitative and semi-quantitative more than 25 techniques and tools, were discussed in risk assessment literature [1, 6, 7, 8,9,10 &11].

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May as researchers and experts attempt to answer the question: (which method we choose and why?) their work covered wide range of application from agriculture, mining, engineering and industries [8, 9, 14] non-of them claimed an optimal due to selection procedure associated with future prediction. The aim of this paper is therefore to contribute to these efforts. This paper will focus on discussing the cross-compatibility between risk assessment methodologies, as well as describes how to select suitable risk assessment methodology. And further explain a range of tools and techniques that can be used to perform a risk assessment or to assist with the risk assessment process. It may sometimes be necessary to employ more than one method of assessment. Two approaches adopted: The first approach discussed the selection of risk assessment method in consideration of availability of resources, uncertainty and factors influencing selection of methods. While the second approach discussed the selection criteria in accordance of consequence assessment and frequency assessment. In the case study the two approaches are utilized to select suitable methods.

2. Methods

Two approaches are employed to achieve the objectives.

2.1 Risk Assessment Methods Selection

Risk assessment may be undertaken in varying degrees of depth and detail and using one or many methods ranging from simple to complex. The form of assessment and its output should be consistent with the risk criteria developed as part of establishing the context. In general terms, suitable techniques should exhibit the following characteristics: [2]

- it should be justifiable and appropriate to the situation or organization under consideration;
- it should provide results in a form which enhances understanding of the nature of the risk and how it can be treated;
- it should be capable of use in a manner that is traceable, repeatable and verifiable.

The reasons for the choice of techniques should be given, with regard to relevance and suitability. When integrating the results from different studies, the techniques used and outputs should be comparable. Once the decision has been made to perform a risk assessment and the objectives and scope have been defined, the techniques should be selected, based on applicable factors such as: [2]

- The objectives of the study. For example, if a comparative study between different options is being undertaken, it may be acceptable to use less detailed consequence models for parts of the system not affected by the difference;

- The needs of decision-makers. In some cases a high level of detail is needed to make a good decision, in others a more general understanding is sufficient;
- the type and range of risks being analyzed;
- The potential magnitude of the consequences. The decision on the depth to which risk assessment is carried out should reflect the initial perception of consequences (although this may have to be modified

once a preliminary evaluation has been completed);

- The degree of expertise, human and other resources needed. A simple method, well done, may provide better results than a more sophisticated procedure poorly done, so long as it meets the objectives and scope of the assessment. Ordinarily, the effort put into the assessment should be consistent with the potential level of risk being analyzed;
- The availability of information and data. Some techniques require more information and data than others;
- The need for modification/updating of the risk assessment. The assessment may need to be modified/updated in future and some techniques are more amendable than others in this regard;
- Any regulatory and contractual requirements.

Various factors influence the selection of an approach to risk assessment such as the availability of resources; the nature and degree of uncertainty in the data and information available, and the complexity of the application (see Table.2).

2.1.2 Availability of resources

Resources and capabilities which may affect the choice of risk assessment techniques include: [2]

- the skills experience capacity and capability of the risk assessment team;
- constraints on time and other resources within the organization;
- the budget available if external resources are required.

2.1.3 The nature and degree of uncertainty

The nature and degree of uncertainty requires an understanding of the quality, quantity and integrity of information available concerning the risk under consideration. This includes the extent to which sufficient information about the risk, its sources and causes, and its consequences to the achievement of objectives is available [2]. Available data do not always provide a reliable basis for the prediction of the future. For unique types of risks, historical data may not be available or there may be different interpretations of available data by different stakeholders. Those undertaking risk assessment need to understand the type and nature of the uncertainty and appreciate the implications for the reliability of the risk assessment results. These should always be communicated to decision-makers [2].

2.1.4 Application of risk assessment during life cycle phases

Risk assessment can be applied at all stages of the life cycle and is usually applied many times with different levels of detail to assist in the decisions that need to be made at each phase. Life cycle phases have different needs and require different techniques For example during the concept and definition phase, when an opportunity is identified, risk assessment may be used to decide whether to proceed or not [2]. Where several options are available, risk assessment can be used to evaluate alternative concepts to help decide which provides the best balance of risks.

During the design and development phase, risk assessment contributes to: [2]

- ensuring that system risks are tolerable,
- the design refinement process,
- cost effectiveness studies,
- identifying risks impacting upon subsequent life-cycle phases.

As the activity proceeds, risk assessment can be used to provide information to assist in developing procedures for normal and emergency conditions [2].

2.1.5 Factors influencing selection of risk assessment techniques

Next the attributes of the methods are described in terms of: [2]

- Complexity of the problem and the methods needed to analyze it,
- The nature and degree of uncertainty of the risk assessment based on the amount of information available and what is required to satisfy objectives,
- The extent of resources required in terms of time and level of expertise, data needs or cost,
- Whether the method can provide a quantitative output.

The following factors should be considered in the selection of a risk assessment method: [4]

• **Cost**:

• **External influences**:

• **Agreement**:

• **Organizational structure**:

• **Adaptability**: A method must be able to adapt to an organization’s needs.

• **Complexity**

• **Completeness**

• **Level of risk**

• **Organizational size**

• **Organizational security philosophy**

• **Consistency**:

• **Usability**:

• **Feasibility**

• **Validity**:

• **Credibility**:

• **Automation**: Automated methods are faster, however the associated loss of human intuition and creativity may led to less economical and less efficient safeguards being selected.

Table 1: Comparison of Hazard Evaluation and Risk Assessment Methods (1)

METHOD	APPLICABILITY														
	Operating Mode		Hazard level		Process or Task Complexity		Number of Scenarios Found		Process Type		Experience with Process or Task		Details Available for Process		
	Continuous	Batch, Startup, Shutdown, online maintenance	Low	High	Low	High	Low	High	Flow	Mechanical, Electrical	Low	High	Low (i.e., conceptual design)	Medium (i.e., detailed design)	High (i.e., pre-startup or operating unit)
QUALITATIVE – Identify and evaluate hazards and judge risk by voting of multi-disciplinary team															
Checklist	X	X	X		X		X		X	X	X	X	X		
Preliminary Hazard Review	X	X		X		X	X		X	X	X		X		
What-If	X	X	X		X		X		X	X	X	X	X	X	X
What-If/Checklist	X	X	X		X		X		X	X	X	X	X	X	X
2 Guide Word		X		X	X			X	X	X		X			X
HAZOP (full set of guide words)	X	X		X		X		X	X		X	X		X	X
FMEA	X			X		X		X		X	X	X		X	X
QUANTITATIVE – Numerically estimate the risk to aid in judgment of a scenario that is already identified; typically not a team															
Fire/Explosion Index	X	X		X	X	X	NA	NA	X			X		X	X
Toxicity Index	X	X		X	X	X	NA	NA	X			X		X	X
LOPA	X	X		X	X	X	NA	NA	X	X		X		X	X
Fault Tree Analysis	X	X		X		X	NA	NA	X	X		X		X	X
Event Tree Analysis	X	X		X		X	NA	NA	X	X		X		X	X
Human Reliability Analysis		X		X		X	NA	NA	X	X	X	X		X	X

The mentioned factors easily can employed to the Table-1 which shows the comparison of hazard evaluation method and table-2 the application of the method is described as being either strongly applicable, applicable or not applicable.

Table 2: Applicability of tools used for risk assessment [2]

Tools and techniques	Risk assessment process				
	Risk Identification	Risk analysis			Risk evaluation
		Consequence	Probability	Level of risk	
Brainstorming	SA[1)]	NA[2)]	NA	NA	NA
Structured or semi-structured interviews	SA	NA	NA	NA	NA
Delphi	SA	NA	NA	NA	NA
Check-lists	SA	NA	NA	NA	NA
Primary hazard analysis	SA	NA	NA	NA	NA
Hazard and operability studies (HAZOP)	SA	SA	A[3)]	A	A
Hazard Analysis and Critical Control Points (HACCP)	SA	SA	NA	NA	SA
Environmental risk assessment	SA	SA	SA	SA	SA
Structure « What if? » (SWIFT)	SA	SA	SA	SA	SA
Scenario analysis	SA	SA	A	A	A
Business impact analysis	A	SA	A	A	A
Root cause analysis	NA	SA	SA	SA	SA
Failure mode effect analysis	SA	SA	SA	SA	SA
Fault tree analysis	A	NA	SA	A	A
Event tree analysis	A	SA	A	A	NA
Cause and consequence analysis	A	SA	SA	A	A
Cause-and-effect analysis	SA	SA	NA	NA	NA
Layer protection analysis (LOPA)	A	SA	A	A	NA
Decision tree	NA	SA	SA	A	A
Human reliability analysis	SA	SA	SA	SA	A
Bow tie analysis	NA	A	SA	SA	A
Reliability centred maintenance	SA	SA	SA	SA	SA
Sneak circuit analysis	A	NA	NA	NA	NA
Markov analysis	A	SA	NA	NA	NA
Monte Carlo simulation	NA	NA	NA	NA	SA
Bayesian statistics and Bayes Nets	NA	SA	NA	NA	SA
FN curves	A	SA	SA	A	SA
Risk indices	A	SA	SA	A	SA
Consequence/probability matrix	SA	SA	SA	SA	A
Cost/benefit analysis	A	SA	A	A	A
Multi-criteria decision analysis (MCDA)	A	SA	A	SA	A

1) Strongly applicable.
2) Not applicable.
3) Applicable.

Methods meet the minimum criteria for the case stud

2.2 Selecting the Appropriate Technique

Each hazard evaluation technique has unique strengths and weaknesses. Understanding these strengths and weaknesses is important in selecting the appropriate hazard evaluation technique. The process of selecting an appropriate hazard evaluation technique may be difficult for an inexperienced facilitator because the "best" technique may not be apparent. As hazard analysts gain experience with various hazard evaluation methods, the task of choosing an appropriate technique becomes easier and somewhat instinctive [5].

2.2.1 Consequence / Impact Assessment

The incidents of concern within the process industries are often, but not always, associated with the loss of containment of material from the process. The material has hazardous properties, which might include toxicity and energy content (e.g., thermal, pressure, or potential combustion energy). Typical incident scenarios might include the rupture or break of a pipeline, a hole in a tank, a runaway reaction in a vessel, fire external to the vessel causing a relief valve to open, an operator erroneously opening a vent or drain valve, etc. Once the incident is defined, a source model(s) is selected to describe how materials are discharged from the process. The source model provides a description of the rate of discharge, the total quantity discharged (or total time of discharge), and the state of the discharge (solid, liquid, vapor, or a combination). Typically, a dispersion model is subsequently used to describe how the material is transported downwind and mixes with air to some concentration level [5]. For toxic releases, effect models consider the concentration and duration of exposure and the mode of physiological impact to convert these incident-specific results into effects on people (injury or death). For flammable releases, fire and explosion models convert information on the concentration and mass of material present (and, perhaps, information describing the physical environment of the flammable cloud) into energy hazard potentials such as thermal radiation and explosion overpressures. Other effect models are then used to estimate effects on people and structures. Additional refinement to consequence estimates may be provided by consideration of mitigation factors, such as isolation systems that might reduce the duration of the release or water sprays, foam systems, and sheltering or evacuation that may reduce the magnitude of potential effects [5].

2.2.2 Frequency Assessment

Guidelines for Engineering Design for Process Safety [5] provides detailed information on the most common techniques to answer the question: *"How often might this incident scenario occur?"* Frequency assessment techniques include:

- Review of historical records of similar events
- Fault tree analysis
- Event tree analysis
- Layer of protection analysis
- External event analysis
- Common cause failure analysis
- Human reliability analysis

In performing frequency analyses, it is often difficult to determine the appropriate level of detail needed to provide sufficient information to make the necessary risk-based decision. Typically, a phased approach, such as the following, should be considered in performing frequency analysis: [5]

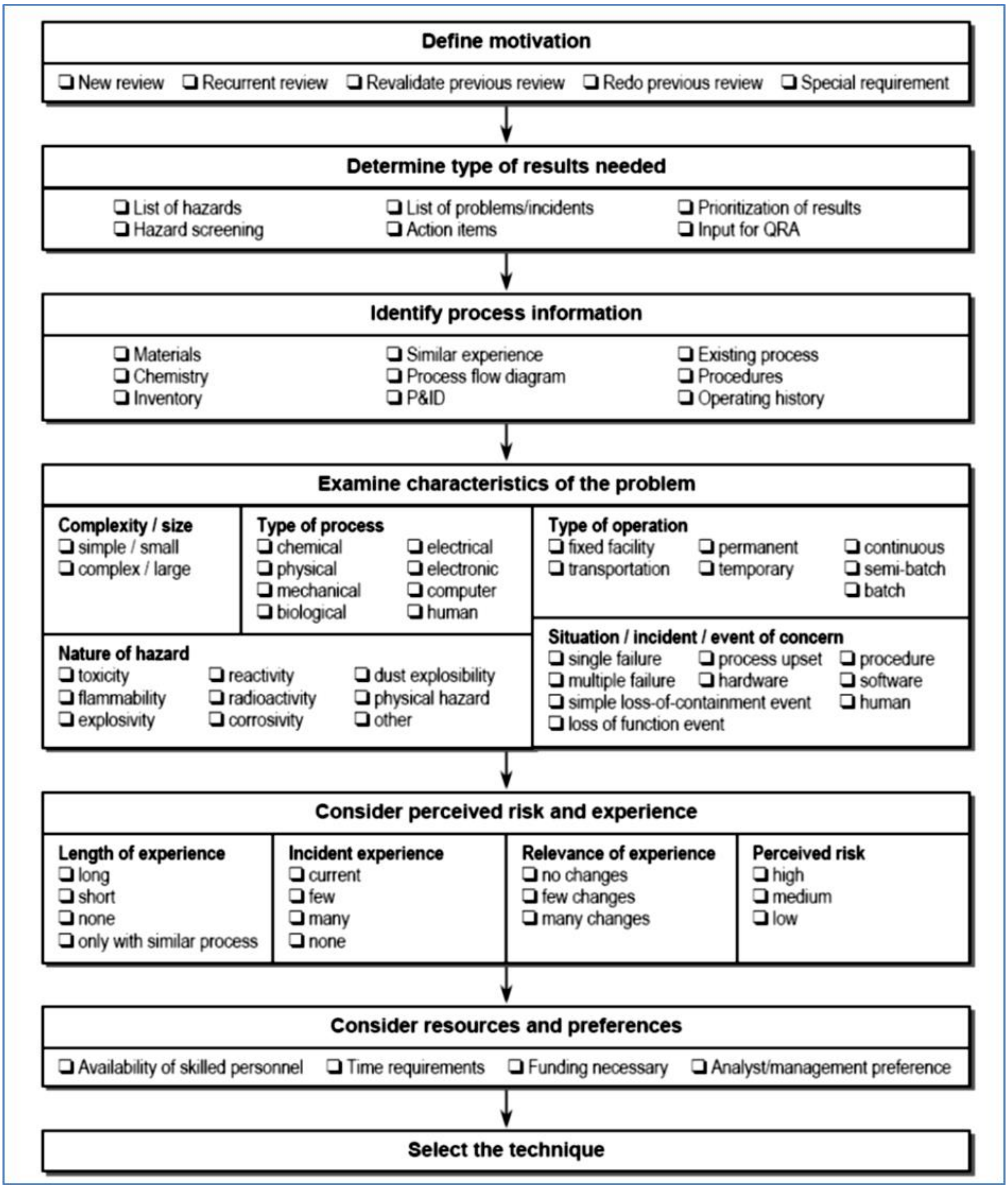
• Perform a qualitative study using, for example, HAZOP or What-if Analysis to identify potential initiating events that could lead to incident scenarios of interest.

• For initiating events of interest, prepare an event tree to further develop the scenarios; e.g., showing the various outcomes which could result based upon the success or failure of relevant protective features.

• Use techniques such as fault tree analysis or the review of historical records to estimate the initiating event frequencies and branch point probabilities for each scenario.

• Calculate the frequency estimates for each scenario outcome by multiplying the initiating event frequency by the appropriate branch point probabilities. Often simplified frequency analyses are performed by providing estimates at the branch point levels without using detailed Fault Tree Analysis [5].

Table 3: CCPS/AIChE, Guidelines for Hazard Evaluation Procedures [1]



3. Discussion

To apply the selection approaches case study suggested risk assessment for Crude Oil Storage Tank. The selection process for risk assessment methods will be as follow:

3.1 Selection Procedure Framework

Guidelines for Hazard Evaluation Procedures (CCPS/AIChE) Table-3 conducted according to the following sequence:

1- Motivation: special requirements for academic study.

2- Determine type of result needed: list of hazards and input for QRA.

3- Process information: Process and Instrumentation Diagrams (P&ID).

4- Examine characteristics of the problem:

- Complexity: simple
- Type of process: chemical
- Type of operation: fixed facility
- Nature of hazards: flammable/ explosively
- Situation of incident event concerned: multiple failure

5- Consider perceive risk and experience:

- Length of experience: long
- Incident experience: many
- Relevance of experience: no change
- Perceived risk: high

6- Consider resource and preference: availability of skilled personnel.

3.2 Justification

1- Comparison of hazard evaluation and risk assessment method, table-1, the most suitable method for this case is HAZOP as Qualitative analysis method because it can offer sufficient details to conduct quantitative analysis. Moreover it is common used in such cases. While for Quantitative analysis: LOPA, FTA and ETA found suitable methods for the case study, but LOPA may need more details. So the study as a comparison case can be conducted by FTA or ETA and that is common used.

2- According to Table -2, it found that HAZOP has the possibility of function analysis which can provide hazard analysis in sufficient details for process equipment. As quantitative analysis FTA and ETA they have the same bath of scenario analysis so any of them can be used for conducting quantitative analysis after HAZOP.

3- According to Table -3, it is found that HAZOP strongly applicable for identifying hazard and analyzing consequence. And it is applicable for probability analysis, risk level analysis and risk evaluation.

On the hand for quantitative analysis:

- FTA strongly applicable for probability analysis. And it is applicable for identifying hazard, risk level analysis and risk evaluation. Not applicable for analyzing consequence.
- ETA strongly applicable for and analyzing consequence. And it is applicable for probability analysis, risk level analysis and identifying. Not applicable for risk evaluation.
- LOPA strongly applicable for probability analysis. And it is applicable for identifying hazard, risk level analysis and analyzing consequence. Not applicable for risk evaluation.

Any one of FTA, ETA or LOPA can be employed with HAZOP. FTA selected to conduct risk evaluation in this case study.

3.3 Conclusion

After this analysis it is suitable to conduct the risk assessment for the case study by using HAZOP as qualitative methodology and for quantitative FTA will be conducted. There is a possibility to mix the two approaches to form one model for selection process.

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