Risk Assessment
9. Preliminary hazard analysis

Stein Haugen stein.haugen@ntnu.no
Marvin Rausand marvin.rausand@ntnu.no

RAMS Group
Department of Production and Quality Engineering
NTNU

(Version 0.1)

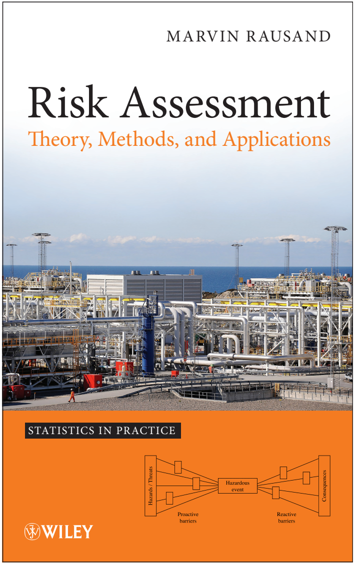
NTNU – Trondheim
Norwegian University of
Science and Technology

Slides related to the book

Risk Assessment
Theory, Methods, and Applications

Wiley, 2011

Homepage of the book:
http://www.ntnu.edu/ross/books/risk



Objective

The objective of this presentation is to give an introduction to preliminary hazard analysis (PHA) and to discuss the tasks that are needed to carry out such an analysis.

What is PHA?

Preliminary hazard analysis (PHA) is a semi-quantitative analysis that is performed to:

1. Identify all potential hazards and hazardous events that may lead to an accident
2. Rank the identified hazardous events according to their severity
3. Identify required hazard controls and follow-up actions

Several variants of PHA are used, and sometimes under different names such as:

- Rapid Risk Ranking
- Hazard identification (HAZID)

What can PHA be used for? - 1

1. As an initial risk study in an early stage of a project (e.g., of a new plant).

   – Accidents are mainly caused by release of energy. The PHA identifies where energy may be released and which hazardous events that may occur, and gives a rough estimate of the severity of each hazardous event. The PHA results are used to (i) compare main concepts, to (ii) focus on important risk issues, and as (iii) input to more detailed risk analyses.

…continues on next slide

What can PHA be used for? - 2

2. As an initial step of a detailed risk analysis of a system concept or an existing system.

   – The purpose of the PHA is then to identify those hazardous events that should be subject to a further, and more detailed risk analysis.

3. As a complete risk analysis of a rather simple system.

   – Whether or not a PHA will be a sufficient analysis depends both on the complexity of the system and the objectives of the analysis.

PHA scope

The PHA shall consider:

- Hazardous components
- Safety related interfaces between various system elements, including software
- Environmental constraints including operating environments
- Operating, test, maintenance, built-in-tests, diagnostics, and emergency procedures
- Facilities, real property installed equipment, support equipment, and training
- Safety related equipment, safeguards, and possible alternate approaches
- Malfunctions to the system, subsystems, or software

– Source: MIL-STD 882C

PHA main steps

1. PHA prerequisites
2. Hazard identification
3. Consequence and frequency estimation
4. Risk ranking and follow-up actions

PHA prerequisites

1. Establish the PHA team
2. Define and describe the system to be analyzed
    - System boundaries (which parts should be included and which should not)
    - System description; including layout drawings, process flow diagrams, block diagrams, and so on
    - Use and storage of energy and hazardous materials in the system
    - Operational and environmental conditions to be considered
    - Systems for detection and control of hazards and hazardous events, emergency systems, and mitigation actions
3. Collect risk information from previous and similar systems (e.g., from accident data bases)

PHA team

A typical PHA team may consist of:

- A team leader (facilitator) with competence and experience in the method to be used
- A secretary who will report the results
- Team members (2-6 persons) who can provide necessary knowledge and experience on the system being analyzed

How many team members who should participate will depend on the complexity of the system and also of the objectives of the analysis. Some team members may participate only in parts of the analysis.

System functions

As part of the system familiarization it is important to consider:

- What is the system dependent upon (inputs)?
- What activities are performed by the system (functions)?
- What services does the system provide (output)?

System breakdown

To be able to identify all hazards and events, it is often necessary to split the system into manageable parts, for example, into three categories:

- System parts (e.g., process units)
- Activities
- Exposed to risk (who, what are exposed?)

Selection of PHA worksheet

The results of the PHA are usually reported by using a PHA worksheet (or, a computer program). A typical PHA worksheet is shown below. Some analyses may require other columns, but these are the most common.

System: Operating mode: Analyst:
Date:

Ref.	Hazard	Accidental event (what, where, when)	Probable causes	Contingencies/ Preventive actions	Prob.	Sev.	Comments

Hazard identification

All hazards and possible hazardous events must be identified. It is important to consider all parts of the system, operational modes, maintenance operations, safety systems, and so on. All findings shall be recorded. No hazards are too insignificant to be recorded. Murthy's law must be borne in mind: "If something can go wrong, sooner or later it will".

Hazard checklist

To get a complete survey of all possible hazards it may be beneficial to use a hazard checklist. Several checklists are available in the literature. An example of a checklist is given at the end of this presentation.

Common sources of hazards

- Sources and propagation paths of stored energy in electrical, chemical, or mechanical form
- Mechanical moving parts
- Material or system incompatibilities
- Nuclear radiation
- Electromagnetic radiation (including infra-red, ultra-violet, laser, radar, and radio frequencies)
- Collisions and subsequent problems of survival and escape
- Fire and explosion
- Toxic and corrosive liquids and gases escaping from containers or being generated as a result of other incidents
- Deterioration in long-term storage
- Noise including sub-sonic and supersonic vibrations
- Biological hazards, including bacterial growth in such places as fuel tanks
- Human error in operating, handling, or moving near equipment of the system
- Software error that can cause accidents

How to identify hazards?

- Examine similar existing systems
- Review previous hazard analyses for similar systems
- Review hazard checklists and standards
- Consider energy flow through the system
- Consider inherently hazardous materials
- Consider interactions between system components
- Review operation specifications, and consider all environmental factors
- Use brainstorming in teams
- Consider human/machine interface
- Consider usage mode changes
- Try small scale testing, and theoretical analysis
- Think through a worst case what-if analysis

Additional data sources

To aid prediction of what can happen in the future it is possible to see what actually has happened in the past:

- Accident reports/databases (MARS, Facts, Woad, etc.) – see Chapter 7 of the textbook.
- Accident statistics
- Near miss/ dangerous occurrence reports
- Reports from authorities or governmental bodies
- Expert judgment

A list of accident data sources may be found on:

http//www.ntnu.edu/ross/books/risk

Frequency and consequence estimation

The risk related to a hazardous event is a function of the frequency of the event and the severity of its potential consequences.

To determine the risk, we have to estimate the frequency and the severity of each hazardous event.

Consequences to consider

A hazardous event may lead to a wide range of consequences, ranging from negligible to catastrophic. A fire may, for example, be extinguished very fast and give minor consequences, or lead to a disaster.

In some applications the severity of an *average* consequence of a hazardous event is assessed.

In other applications we consider several possible consequences, including the worst foreseeable consequence of the hazardous event.

Severity classes

The severity of an event may be classified into rather broad classes. An example of such a classification is:

Rank	Severity class	Description
4	Catastrophic	Failure results in major injury or death of personnel.
3	Critical	Failure results in minor injury to personnel, personnel exposure to harmful chemicals or radiation, or fire or a release of chemical to the environment.
2	Major	Failure results in a low level of exposure to personnel, or activates facility alarm system.
1	Minor	Failure results in minor system damage but does not cause injury to personnel, allow any kind of exposure to operational or service personnel or allow any release of chemicals into the environment.

Frequency estimation - 1

When estimating the frequency of an event, we have to bear in mind which consequences we consider.

In some applications we estimate the frequency of each hazardous event. To be used in risk ranking, this frequency has to be related to the severity of an *average* consequence of each particular hazardous event.

In other applications we consider specific (e.g., worst case) consequences of a hazardous event. We must then estimate the frequency that the hazardous event produces a specific consequence. This may involve a combined assessment, for example, the frequency of the hazardous event, the probability that personnel are present, the probability that the personnel are not able to escape, and so on.

Frequency estimation - 2

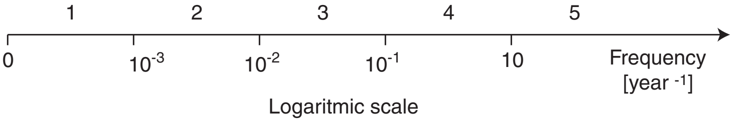
This means that for each hazardous event, we may want to present several consequences with associated frequencies. Consider a hazardous event where an operator falls from a work platform of low height. In most cases the consequence of such a fall will be a minor injury (low severity and rather high frequency). In a very seldom case, the fall may result in a fatality (high severity and very low frequency). Both consequences should be recorded in the PHA worksheet.

In some applications we may want to present both the frequency of the hazardous event and frequencies of various consequences. These may be included in separate columns in a (revised) PHA worksheet.

Frequency classes

The frequency of events may be classified into rather broad classes. An example of such a classification is:

1	Very unlikely	Once per 1000 years or more seldom
2	Remote	Once per 100 years
3	Occasional	Once per 10 years
4	Probable	Once per year
5	Frequent	Once per month or more often



Risk ranking

The risk is established as a combination of a given event/consequence and a severity of the same event/consequence. This enables ranking of the events/consequences in a *risk matrix*:

Frequency/ consequence	1 Very unlikely	2 Remote	3 Occasional	4 Probable	5 Frequent
Catastrophic					
Critical					
Major					
Minor					

Acceptable - only ALARP actions considered

Acceptable - use ALARP principle and consider further investigations

Not acceptable - risk reducing measures required

Risk levels and actions

Each entry in the PHA worksheet may be given a specific risk level, for example, as (from Norsk Hydro, 2002):

Level	Name	Description
H	High	High risk, not acceptable. Further analysis should be performed to give a better estimate of the risk. If this analysis still shows unacceptable or medium risk redesign or other changes should be introduced to reduce the criticality.
M	Medium	The risk may be acceptable, but redesign or other changes should be considered if reasonably practical. Further analysis should be performed to give a better estimate of the risk. When assessing the need of remedial actions, the number of events of this risk level should be taken into account.
L	Low	The risk is low and further risk reducing measures are not required.

PHA pros and cons

Pros:

- Helps ensure that the system is safe
- Modifications are less expensive and easier to implement in the earlier stages of design
- Decreases design time by reducing the number of surprises

Cons:

- Hazards must be foreseen by the analysts
- The effects of interactions between hazards are not easily recognized

Reviewing and revising a PHA

Review/update a PHA whenever:

- The system matures and more is learned about it
- The system equipment is modified
- Maintenance or operating procedures change
- A mishap or near-miss occurs
- Environmental conditions change
- Operating parameters or stress change

Hazard checklist

Several hazard checklists have been published. The following lists give a brief summary of some relevant hazards. Please see the textbook Chapter 3 for more details.

Mechanical hazards - 1

Properties of machine parts or workpieces, such as:

- Shape
- Relative location
- Mass and stability (potential/kinetic energy)
- Inadequacy of mechanical strength
- Accumulation of energy inside the equipment, e.g.:
  - Elastic elements (springs)
  - Liquids and gases under pressure
  - The effects of vacuum

Mechanical hazards - 2

- Crushing hazard
- Shearing hazard
- Cutting or severing hazard
- Entangling hazard
- Drawing-in or trapping hazard
- Impact hazard
- Stabbing or puncture hazard
- Friction or abrasion hazard
- High pressure fluid injection or ejection hazard

Electrical hazards

- Contact of persons with live parts (direct contact)
- Contact of persons with parts which have become live under faulty conditions (indirect contact)
- Approach to live parts under high voltage
- Electrostatic phenomena
- Thermal radiation or other phenomena such as the projection of molden particles and chemical effects from short circuits, overloads, etc.

Thermal hazards

- Burns, scalds and other injuries by a possible contact of persons with objects or materials with an extreme high or low temperature, by flames or explosions and also by radiation of heat sources
- Damage to health by hot or cold working environment

Thermodynamic hazards

- Overpressure
- Underpressure
- Over-temperature
- Under-temperature

Hazards generated by noise

Resulting in:

- Hearing loss (deafness), other physiological disorder (e.g., loss of balance, loss of awareness)
- Interference with speech communication, acoustic signals, etc.

Hazards generated by vibration

- Use of hand-held machines resulting in a variety of neurological and vascular disorders
- Whole body vibration, particularly when combined with poor postures

Hazards generated by radiation

- Low frequency, radio frequency radiation, micro waves
- Infrared, visible and ultraviolet light
- X and gamma rays
- Alpha, beta rays, electron or ion beams, neutrons
- Lasers

Hazards generated by materials/substances

- Hazards from contact with or inhalation of harmful fluids, gases, mists, fumes, and dusts
- Fire or explosion hazard
- Biological or microbiological (viral or bacterial) hazards

- Flammables (ignition, fire, explosion/detonation)
- Chemicals (toxicity, corrosion, off-specification)
- Pollutants (emissions, effluents, ventilation)