BME2012
Occupational Health And Safety 2
Week 2-3-4

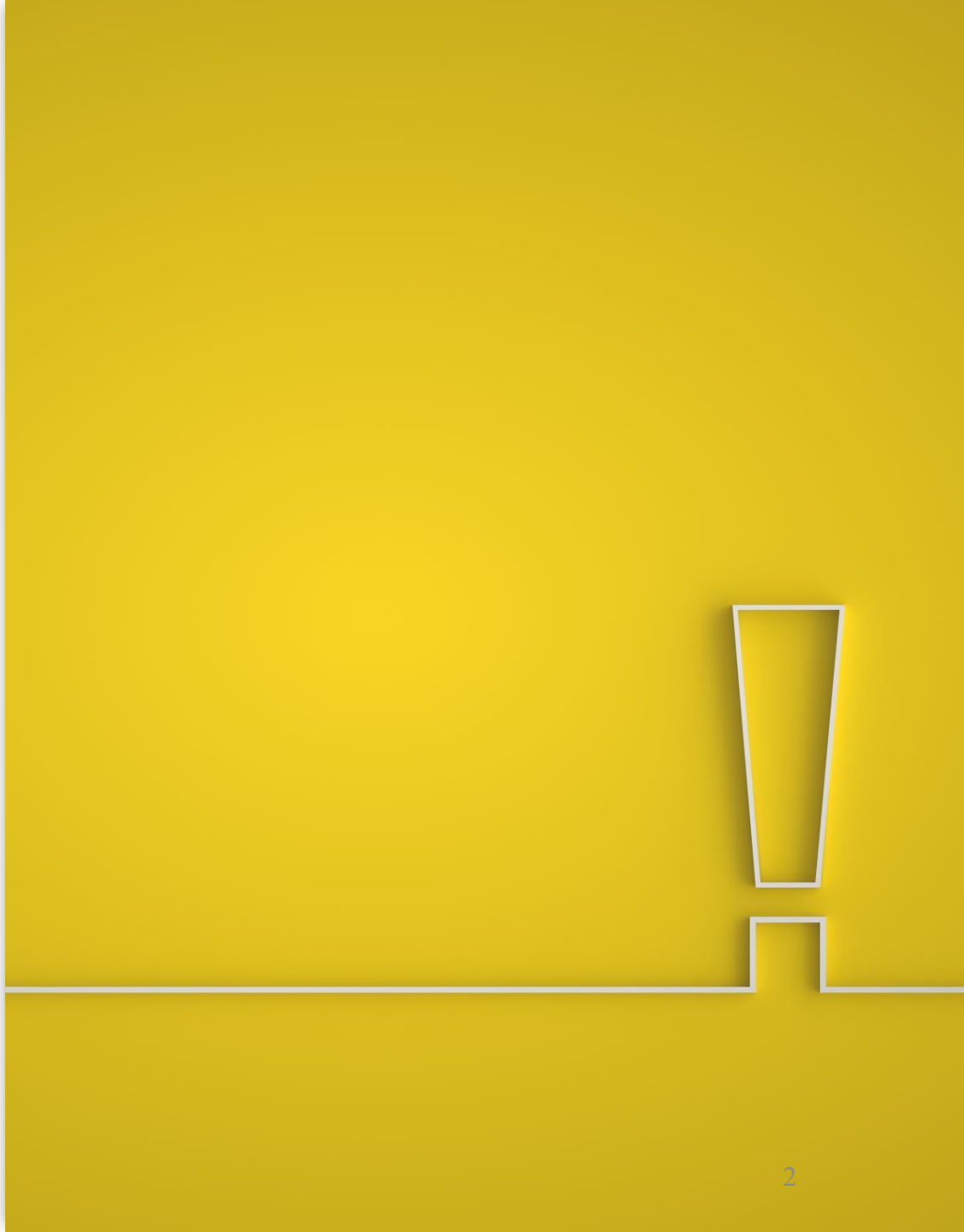
Department of Biomedical Engineering, Faculty of Electrical and Electronic Engineering,

Yıldız Technical University

Course Coordinator : Prof. Mihrigül EKŞİ ALTAN
Instructor: Ress.Asst. Yeliz GÜLDORUM

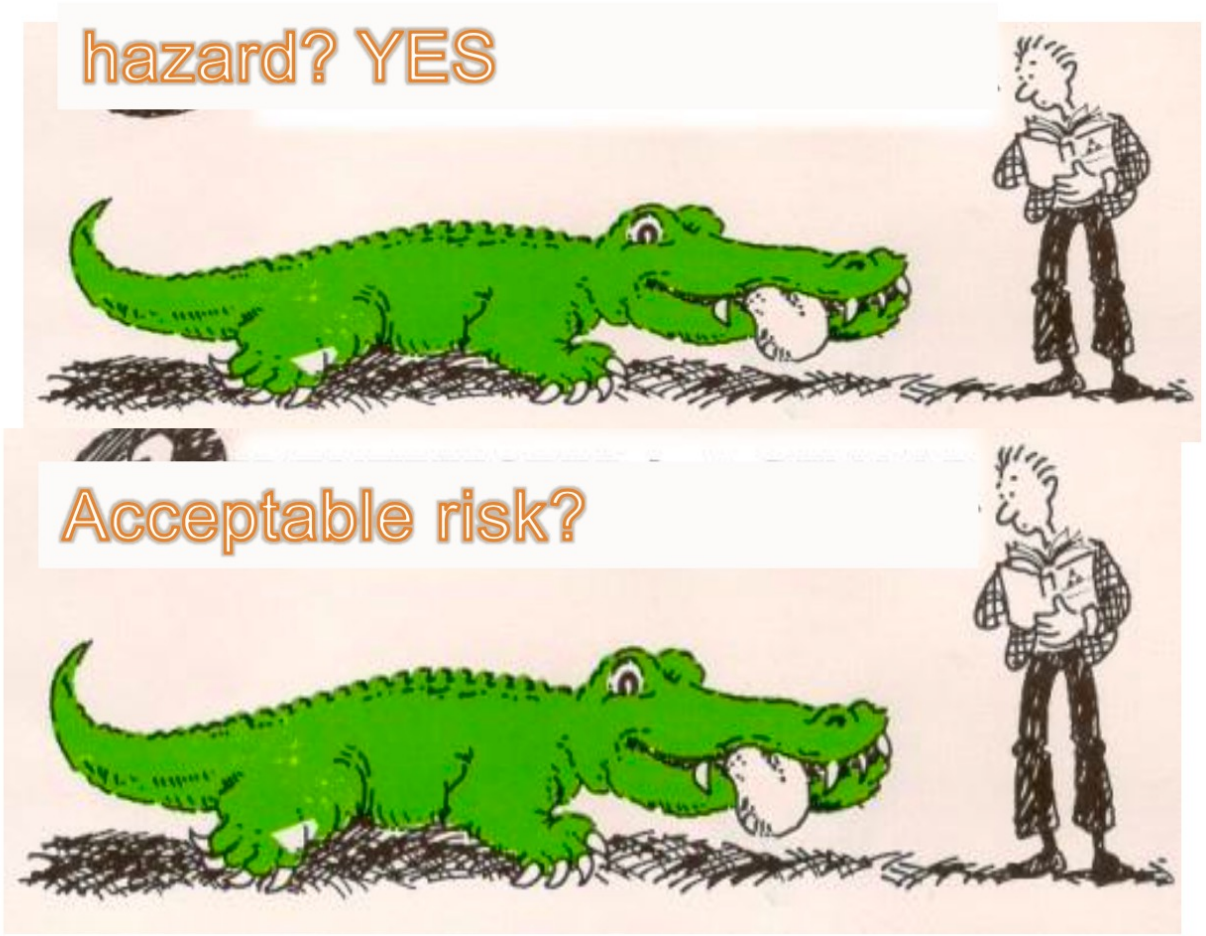
Principles underlying risk management

- Most hazardous conditions at work are preventable
- Occupational accidents and diseases can be managed
- Prevention is preferred to protection
- Proactive approaches are preferred to reactive approaches
- Actions on the working environment are preferred to actions on individuals

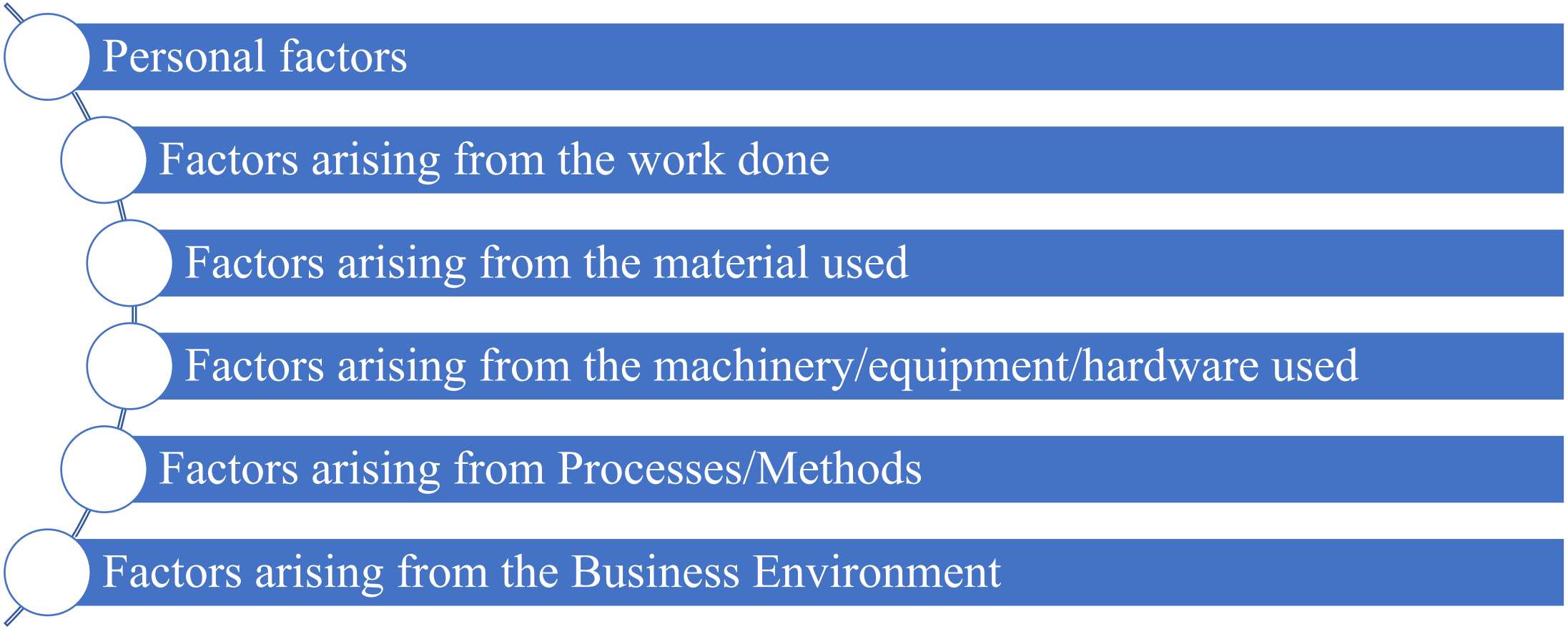


- A **hazard** is an agent, condition or activity with potential to cause harm that, if left uncontrolled, may adversely affect the well-being or health of exposed people

- A **risk** is a combination of the likely severity and probability that somebody will actually be harmed by a specific hazard



Sources of Danger



Alternative Classification-1

- **PHYSICAL**

MECHANICS: Falls from heights, Impacts, Sinkings, Vibration, Slips – Falls etc.
THERMAL: Temperature/Flame, Cold etc.
ELECTRICAL: Electricity Leakage, Short Circuit, Fire etc.
RADIATION: Ionizing Radiation, Non-ionizing Radiation
NOISE: Working in a Noisy Environment, etc.

Alternative Classification-1

- **CHEMICAL**

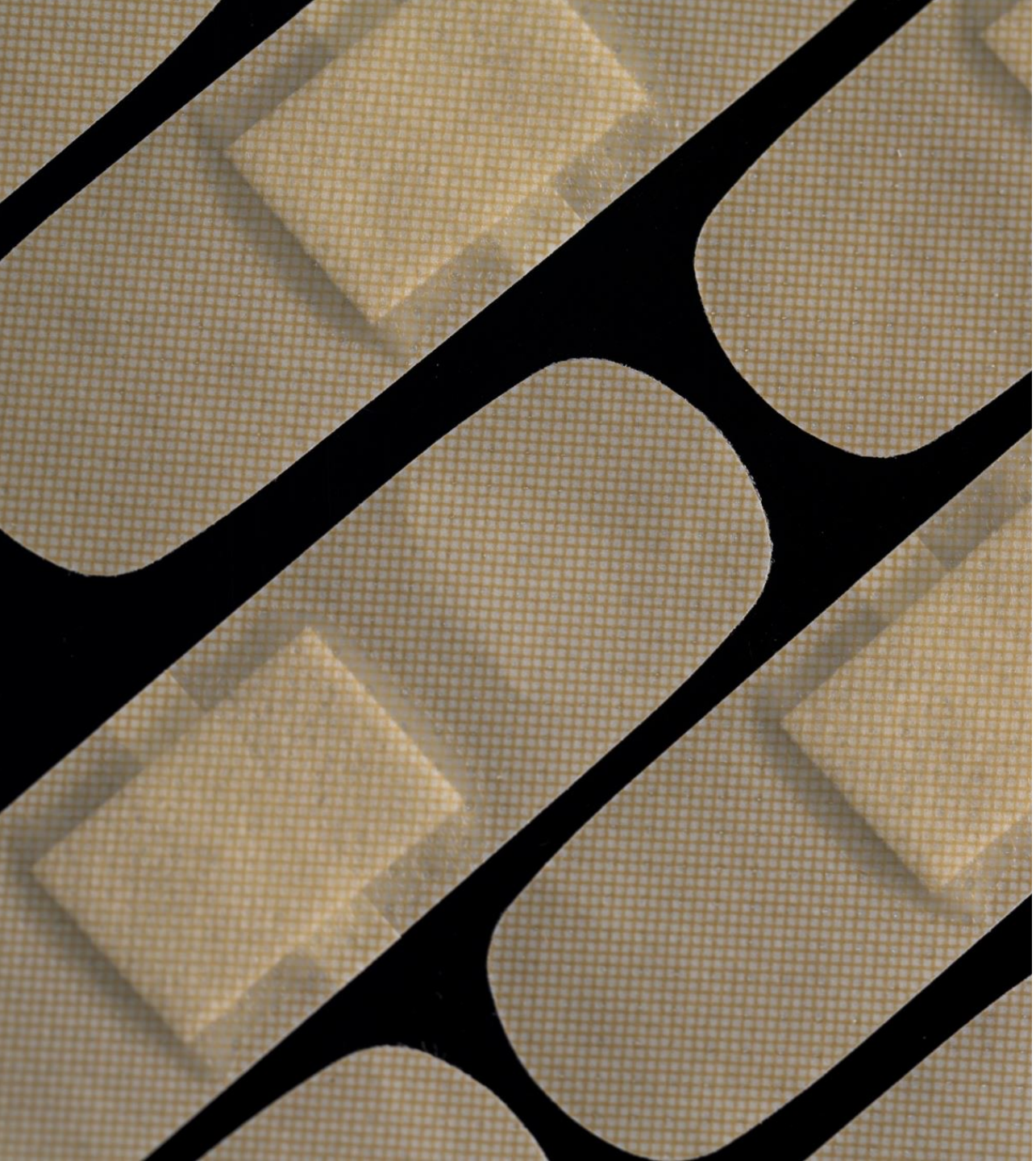
AEROSOLS: Dusts/Fibres, Smoke, Vapor, Fire, etc.
LIQUIDS: Submergence, Splashing, Burning, etc.
GASES/VAPORS: Gas Accumulation/Explosion, Fire, Toxic Gas Inhalation, etc.

Alternative Classification-2

Biological : Harmful Bacteria
Harmful Viruses
Mushrooms Non-microbıological Antigens

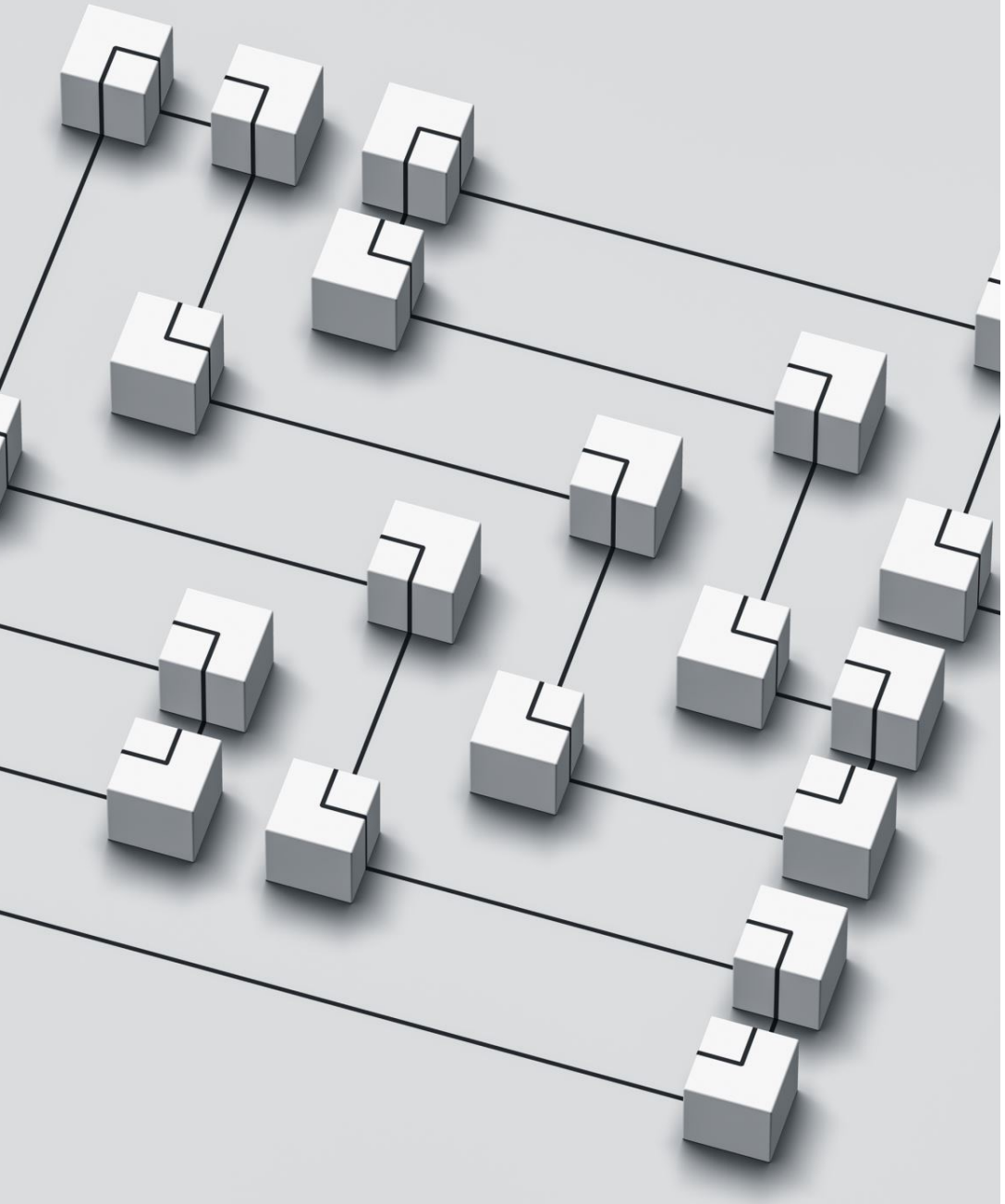
Psycho-social

Ergonomıc



Occupational Safety Risks

- Blows, cuts, bruises
- Sprain, strain
- Injury
- Burn
- Hand/ Foot fracture
- Poisoning
- Flu, asthma, pneumonia and other chest infections
- Concussion
- Deafness, hearing loss, etc.

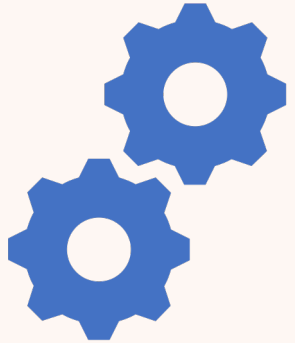


Risk Control Principles

- Principle of Systematicity
- Collective Protection Principle
- Not Creating Additional Risk
- Principle of Protection and Prevention
- Principle of Economicality
- Principle of Specificity of Risks
- Risk Perception Variability Principle
- Principle of Subjectivity
- Participation Principle

Risk Control Principles

Proactive Approach Principle
Principle of Not Incurring Financial Burden



Principle of Increasing the Protection Level
Principle of Integration into Other Systems
Review and Continuous Improvement Principle


Risk Assessment

Purpose of Risk Assessment

- Identifying hazards,
- Evaluating the probability of occurrence of each hazard and the degree of severity of possible consequences,
- Reviewing the effectiveness of existing controls,
- Identifying high risks that require urgent measures,
- Identifying risks that require precautions in the medium term,
- Precautions to be taken to reduce these risks to acceptable levels determined, implemented and monitored.

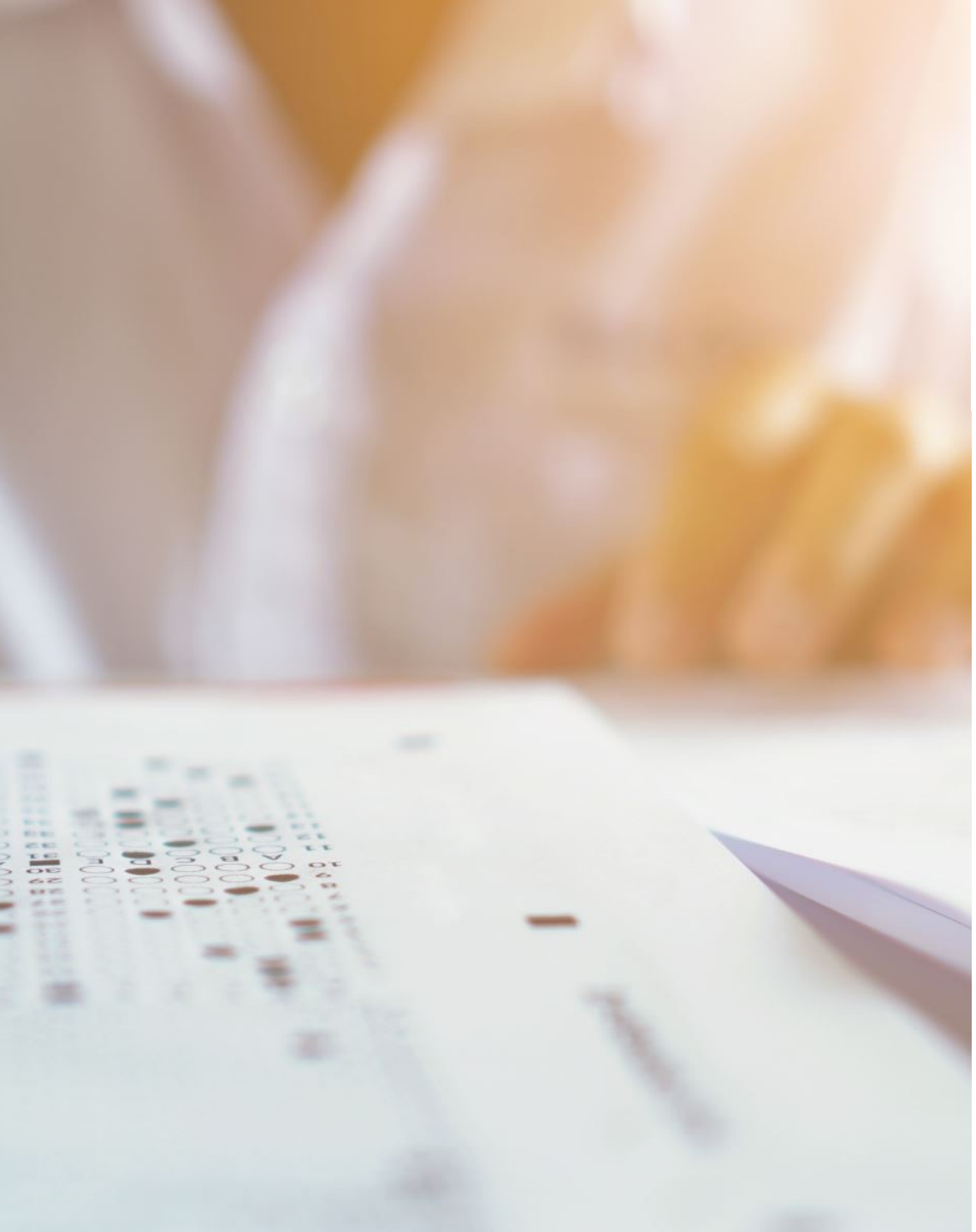
When Should Risk Assessment Be Done?

- When starting work or if it has never been done before,
- In case of any change at work or workplace,
- After a work accident, occupational disease or a near miss,
- At regular intervals.

When Should Risk Assessment Be Done?

- In the 6th article titled risk assessment of the regulation on OSH measures in working with chemical substances;

Risk assessment will be renewed in the following cases;
1) Within the periods determined in the risk assessment,
2) When there is a significant change in working conditions,
3) When necessary, based on the results of environmental measurements and health surveillance,
4) When any accident occurs due to chemical substances,
5) At least once every five years.



Who Should Perform the Risk Assessment?

Risk Assessment Team

It is an important issue who will carry out risk assessment studies. There are two basic views accepted by experts on this subject.

1) (Team Approach): Risk assessment is an important task and should be done by expert teams.

2) (Individual Approach): Risk assessment studies should be carried out by an individual or a team, depending on the characteristics of the business.

Team Approach

Main Benefits

- Necessary information can be provided by all employees,
- Results that will satisfy everyone can be achieved,
- Provides participants with a spirit of belonging and cooperation,
- Participation of managers ensures that employees also own the results supports.

Main Drawbacks

- Results may be obtained later from team work,
- Interaction within the team may negatively affect the result,
- The time required to work and the cost are high.

Team Approach

Things to Consider When Creating a Risk Assessment Team Topics:

- Team members should be determined according to **their abilities,**
- **The professions** of the team members must be **suitable** for the subject to be risk assessed,
- Team members should choose a **leader** from among themselves,
- The team **leader** knows the business and risk assessment techniques **well.**
- An **appropriate** risk assessment **method** should be selected,
- Every stage of the evaluation should be **recorded,**
- When working in different departments, **choices** should be made taking into account **business knowledge and expertise,**

Team Approach

Things to Consider When Creating a Risk Assessment Team Topics:

- **Techniques that** will ensure the participation of all employees should be used,
- Interactions and interventions within and outside the team should be taken into account,
- Working in the department where risk assessment studies are carried out appropriate consultation of workers should be sought,
- Significant resource use should be made by management.

Team Approach

The risk assessment team should be composed of at least the following members, taking into account the number of workers and the characteristics of the work and workplace.

- Employer or her/his representatives,
- Workplace OHS specialist,
- Workplace physician,
- Employees or their representatives,
- Authorized technical director of the department where risk assessment studies are carried out.

Individual Approach

- The approach that risk assessment is carried out by the individual in cases where **the workplace** is small and OHS **risks are low.** It is an acceptable option.
- Regulations allow this in some **special cases**.

Individual Approach

Main Benefits:

- Provides quick results,
- Independent action, quick decision-making alone, rapid implementation
- It prevents the person from being directed by her/his colleagues,
- They are not negatively directed by people in hierarchically higher positions.
- The individual's self-confidence increases,
- It has low cost.

Individual Approach

Main Disadvantages

- Requires technical expertise,
- For beneficial results, the job, workplace, transactions, risk, It should be carried out by a person who knows the evaluation technique well and is familiar with the OHS legislation.
- Management approach,
- OHS issues concern everyone. Therefore, the contribution of every segment of the workplace should be ensured.
- One-dimensionality,
- The success rate depends on the education, experience, knowledge and knowledge of the person doing the evaluation.
- Since there is no participation, people feel that the dangers are in their own departments. They think it is not,
- In cases where participation in the evaluation is not ensured, employees may not care about the recommended measures,
- Different comprehension levels of individuals may affect the evaluation.

Risk Assessment Process in 5 Steps

So far, we have discussed the importance of Risk Assessment:

- In terms of **OHS Management System**
- In terms of **legislation.**

We talked about the concept and cycle of **continuous improvement.**

We talked about **the proactive approach.**

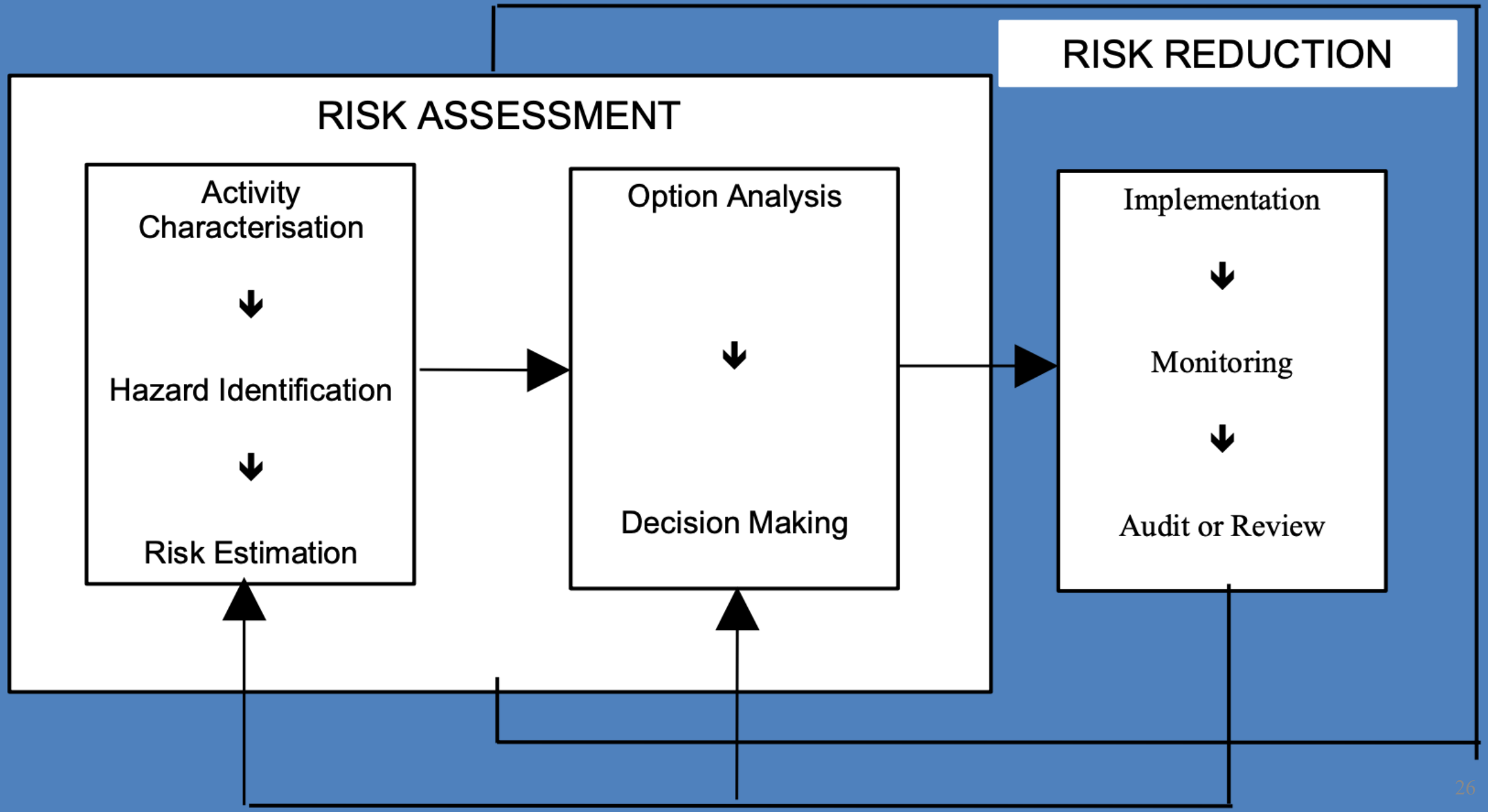
- A practical methodology (approach) is needed.

Risk Assessment Process in 5 Steps

In Risk Assessment we look for answers to these practical questions:

- What could go **wrong ?**
- What is **the probability** of this ?
- What kind of **consequences** could it cause if it happens?
- **What are the risks?**
- Are these risks **at an acceptable level?**
- How can risks **be reduced?**

RISK MANAGEMENT



Step 1,
Identifying Hazards

These 3-questions allow us to identify hazards;

What are the Sources of Danger ?

Who or what could be harmed by this danger?

How can harm occur?

Overlooked Hazard Types

I. THOSE THAT CANNOT BE NOTICED BY NON-EXPERTS

Research and observation are required,

5W-1H questions should be asked

II. NON-ROUTINE SITUATIONS

Dangerous behavior, rude jokes

III. HIDDEN AND INDIRECT DANGERS

Those that arise as a result of other events

Step 1, Identifying Hazards

A)Review of past records
B)Examining the current situation
C)Review of legislation and literature

Total = Workplace Hazards

Step 1, Identifying Hazards (Grouping of Hazards)

1. Legislation- based grouping
2. Process- based grouping
3. Settlement- based grouping
4. Scientific based grouping
5. Mixed grouping

Step 1, Identifying Hazards Grouping of Hazards

1. Legislation-based risk grouping:

- Regulation on OHS Precautions in Working with Chemical Substances.
- Regulation on Health and Safety Measures to be Taken in Workplace Buildings and Extensions
- Regulation on Health and Safety in Construction Works
- Regulation on Health and Safety Conditions in the Use of Work Equipment
- About Health and Safety Precautions in Working with Asbestos regulation
- About Health and Safety Precautions When Working with Screened Vehicles regulation
- Manual Handling Regulations
- Noise Regulation
- Vibration Regulation
- Safety and Health Signs Regulation
- Protection of Employees from the Dangers of Explosive Environments Regulation on

Step 1, Identifying Hazards Grouping of Hazards

1. Legislation-based risk grouping:

- Health and Safety Conditions in Underground and Surface Mining Enterprises Regulation
- Health and Safety Conditions in Enterprises Extracting Mines by Drilling Regulation
- Personal Protective Equipment (PPE) Regulation ÿ Regulation on the Use of PPE
- Regulation on Carcinogenic and Mutagen Substances
- About Preventing Risks of Exposure to Biological Factors regulation
- Regulation on OHS in Temporary or Fixed-Term Works ,
- Regulation on Health and Safety Measures in Work on Fishing Vessels
- Regulation on Working Conditions of Pregnant or Breastfeeding Women, Breastfeeding Rooms and Child Care Dormitories
- Regulation on Workplace Health and Safety Units and Joint Health and Safety Units .

Step 1, Identifying Hazards Grouping of Hazards

2. Process based grouping:

A management system at work

- TS ISO 9001, Quality Management System
- TS ISO 14001, Environmental Management System
- TS OHSAS 18001, OHS Management System

This approach can be applied if the processes have been established and the processes have been determined.

Step 1, Identifying Hazards Grouping Hazards

3. Grouping based on location:

Can you spot the Workplace Hazards?

Find the 8 hazards in this office scene.

1. **Cable runs across floor**
   TRIPPING HAZARD
2. **Overloaded plug socket**
   FIRE HAZARD
3. **Lifting boxes with bad posture**
   MANUAL HANDLING
4. **Only one foot on a ladder**
   WORKING AT HEIGHTS
5. **Slip hazard from leak/spillage**
   SLIPS & TRIPS
6. **Handbag blocking fire exit**
   FIRE RISK
7. **Falling objects**
   GENERAL HAZARD
8. **Slumped in computer chair**
   DSE

Step 1, Identifying Hazards Grouping Hazards

4. Scientific based grouping:

Step 1, Identifying Hazards Grouping of Hazards

5. Mixed grouping:

It is the most used method.

It is a grouping that starts from the entrance of the workplace , sequentially according to the layout and workflow , and if necessary, scientific- based groupings or legislation- based groupings are nested within each section .

Step 2
Identify and Rate Risks

Identify and Rate Risks

DANGER	RISK
Working environment: Indoor	Possibility of carbon monoxide poisoning for workers using a gasoline-powered pump in a well (poorly ventilated area)
Energy: Electricity	Possibility of hitting the worker using a power tool with inadequate insulation
Manual Transport	The probability of a worker carrying 40 kg loads suffering a back injury
Noisy	Workers working near a machine with a continuous sound intensity level above 80 dB(A) are likely to suffer from permanent hearing loss.
Noisy	The possibility of workers in an office becoming stressed in the form of fatigue, anxiety, anxiety and/or aggression as a result of exposure to low noise levels below a constant 75 dB(A)
Substance: Infectious blood	Possibility of infectious disease due to injection injury when taking a blood sample from a patient with an infectious disease
Workplace Press machine	Possibility of losing fingers of a worker working on a press without protection

Identify and Rate Risks

Risk assessment is the process of estimation and evaluation of all the risks associated with each hazard identified.

The risk associated with a hazard is a combination of:

- the severity of the harm (CONSEQUENCES) and
- the probability (LIKELIHOOD) that the event will occur.

Identify and Rate Risks

Risk is defined as:

the likelihood of the hazardous event × the severity of the most likely loss in the circumstances which will be abbreviated to '**likelihood × severity**'.

Risk = likelihood × severity

Risk assessment: an example of how to do it

A possible technique includes 5 steps:

1st step: Estimate the **probability** of each hazard – previously identified – according to its likelihood of occurrence (very likely; likely; quite possible; possible; not likely) and assign the quantitative value accordingly.

2nd step: Estimate the **severity** of each hazard according to its potential of the harm (very high, high; moderate; slight; nil) and assign the quantitative value accordingly.

Likelihood

- There are different views on what constitutes likelihood in the context of risk rating. The preferred measure of likelihood is the likelihood of a hazardous event.

- The likelihood of the hazardous event is defined independently of the possible outcomes.

For example, the likelihood of tripping is rated, irrespective of whether the person who trips will be hurt.

Identify and Rate Risks

The following factors may affect the likelihood of an accident or incident occurring;

- People exposed to risk,
- Type, frequency and duration of risk exposure,
- Relationship between risk exposure and its effects,
- Human factors,
- Reliability of security functions,
- Possibilities of making security measures ineffective or misleading,
- Ability to maintain security measures

Identify and Rate Risks

A)

Rating	Probability	Qualitative description
1	< 0.2	Very unlikely
2	0.2–0.39	Unlikely
3	0.4–0.59	Likely
4	0.6–0.79	Very likely
5	> 0.79	Almost certain

B)

CONCLUSION		RATING
(1) VERY LIGHT:		No loss of work hours, no need for first aid
(2) LIGHT	:	No loss of working days, requiring first aid
(3) MEDIUM	:	Minor injury, treatment required
(4) SERIOUS	:	Death, serious injury, occupational disease
(5) VERY SERIOUS	:	Multiple deaths or permanent disability

A) Scale for rating likelihood of a hazardous event.

B) The following scale can be used to rate the expected damage after a possible event.

Identify and Rate Risks

POSSIBILITY		RATING
(1) Very small probability	:	Once a year
(2) Small probability	:	Once in a month
(3) Moderate probability:		Once a week
(4) High probability	:	Every day
(5) Very high probability	:	as long as the work is done

Likelihood

- Examples of how these scales can be used include
- Rating 1 ($p < 0.19$). The likelihood that a person will fall down a manhole with an intact, properly fitted cover. The likelihood that a person will push too hard when opening a conventional room door.
- Rating 3 ($p = 0.4 – 0.59$). The likelihood that a person will fall down an open manhole protected only by a flimsy barrier. The likelihood that someone will push too hard when pushing a broken-down car with help from three other people.
- Rating 5 ($p > 0.79$). The likelihood that a person will fall down an open manhole which has *no barrier* and *no warning signs*. The likelihood that someone will push too hard when pushing a broken-down car uphill unassisted

Severity

A number of different types of severity could be used in severity ratings, and some examples are given below:

- The severity of the most serious harm which could occur. For example, if a person trips, the most severe harm could be a fatality.
- The severity of the most likely harm in the circumstances. For example, if a person trips in an office, the most likely harm is a bruise.
- The combined severity of all the harms which could occur, taking into account their different probabilities

Severity

Factors affecting the likelihood that a person will fall down a manhole include:	Factors affecting the severity of harm if a person falls down a manhole include:
the size of the opening	the depth of the manhole
the lighting	whether there are opportunities to arrest the fall
whether there is a barrier	what is at the bottom of the shaft
whether there are warning signs	

- The severity scale is the severity of the most likely harm in the circumstances.
- Note that there are different factors that influence likelihood and severity. Factors affecting the likelihood that a person will fall down a manhole include:

Severity

Scale for rating severity of most likely harm

Rating	Cost scale	Time away from work	Qualitative description
1	< £100	< 1 hr	No injury or trivial injury
2	£100–£999	1 hr < 1 day	Minor injury
3	£1,000–£4,999	1–5 days	Serious injury
4	£5,000–£24,999	6–15 days	Very serious injury
5	> £24,999	> 15 days	Disabling injury or fatality

3rd step: Once the **probability** and the **severity** of the hazard is determined, by multiplying these two factors, a range of **risk** ratings between 1 and 25 will be obtained

Risk = **likelihood (the likelihood of occurence)** × **severity (severity of harm)**

RISK ASSESSMENT GRID

Probability	Severity: Very high 5	High 4	Moderate 3	Slight 2	Nil 1
Very likely 5	25	20	15	10	5
Likely 4	20	16	12	8	4
Quite possible 3	15	12	9	5	3
Possible 2	10	8	6	4	2
Not likely 1	5	4	3	2	1

Risk assessment: an example of how to do it

4th step: Risk evaluation, criterion of actions:

Urgent situation (20 to 25) requires action immediately

High-risk situations (10 to 16) require action in the short and medium-term

Medium-risk situations (5 to 9) require action or further evaluation within an appropriate period

Low-risk situations (less than 5) may require relatively little or no action

5th step: After the comparison with the criterion for action, the risks are assigned a priority for risk control through the use of a risk rating

A simple risk-based control plan

RISK LEVEL	ACTION AND TIMESCALE
TRIVIAL	No action is required and no documentary records need to be kept.
TOLERABLE	No additional controls are required. Consideration may be given to a more cost-effective solution or improvement that imposes no additional cost burden. Monitoring is required to ensure that the controls are maintained
MODERATE	Efforts should be made to reduce the risk, but the costs of prevention should b e carefully measured and limited. Risk reduction measures should be implemented within a defined time period. Where the moderate risk is associated with extremely harmful consequences, further assessment may be necessary to establish more precisely the likelihood of harm as a basis for determining the need for improved control measures.
SUBSTANTIAL	Work should not be started until the risk has been reduced. Considerable resources may have to be allocated to reduce the risk. Where the risk involves work in progress, urgent action should be taken.
INTOLERABLE	Work should not be started or continued until the risk has been reduced. If it is not possible to reduce risk even with unlimited resources, work has to remain prohibited.

Step 3 Decide on Control Measures

Step 3 Decide on Control Measures

In this step, the necessary control measures are decided to reduce the risks to an acceptable level.

1) Preventive Measures: Measures to reduce the possibility

2) Protective Measures: Measures to reduce violence

Hierarchical Order of Risk Control Measures

1- Elimination of dangers, (Trying to eliminate risks at their source)

2- Replacing the dangerous with the less dangerous (Substitution)

3- Applying engineering measures;

- Automation,
- Isolation (separation)
- Removal,
- Ventilation,
- Utilizing ergonomic approaches.

4- Administrative measures/Signs/warnings

- Working hours,
- Workplace order,
- Education and Training,
- Planned maintenance-repair
- Mental risks, monotony, communication
- Control-Discipline,

5- Personal protective equipment;

Training, Supply, Availability

Step 4
Complete Control Measures

Complete Control Measures

In this step, the selected control measures are completed by applying them in the workplace.

Completion of control measures includes the following;

- Development of working methods
- Communication
- Providing education and training
- Audit
- Maintenance

Step 5
Monitoring and Repeat

Monitoring and Repeat

The last step is to monitor the effectiveness of the measures and review them repeatedly.

At least the following questions should be answered in this step.

Have the selected control measures been completed as planned?

Are the control measures chosen appropriate?

Have these control measures been implemented correctly?

Does the selected method work?

Have the control measures introduced new and additional risks?

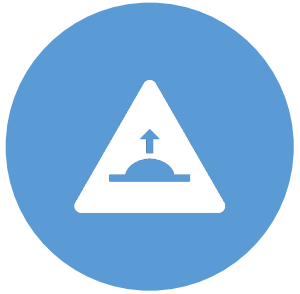
Has exposure to assessed risks been eliminated or sufficiently reduced?

Controlling Risk

Risk Avoidance – This strategy involves a conscious decision on the part of the organisation to avoid completely a particular risk by discontinuing the operation producing the risk e.g. the replacing a hazardous chemical by one with less or no risk potential.

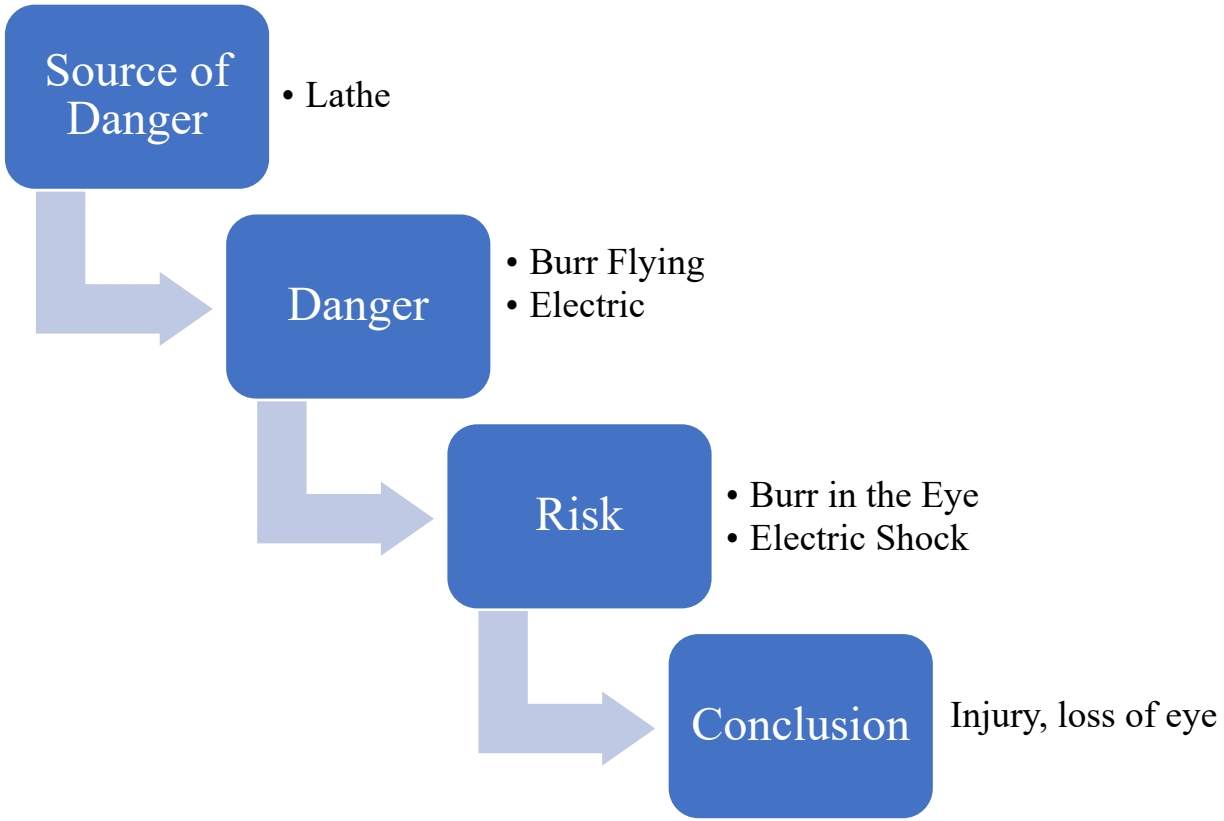
Risk Retention – The risk is retained in the organisation where any consequent loss is financed by the company. There are two aspects to consider here, risk retention with knowledge and risk retention without knowledge.

Risk Transfer – This refers to the legal assignment of the costs of certain potential losses from one party to another. The most common way is by insurance.

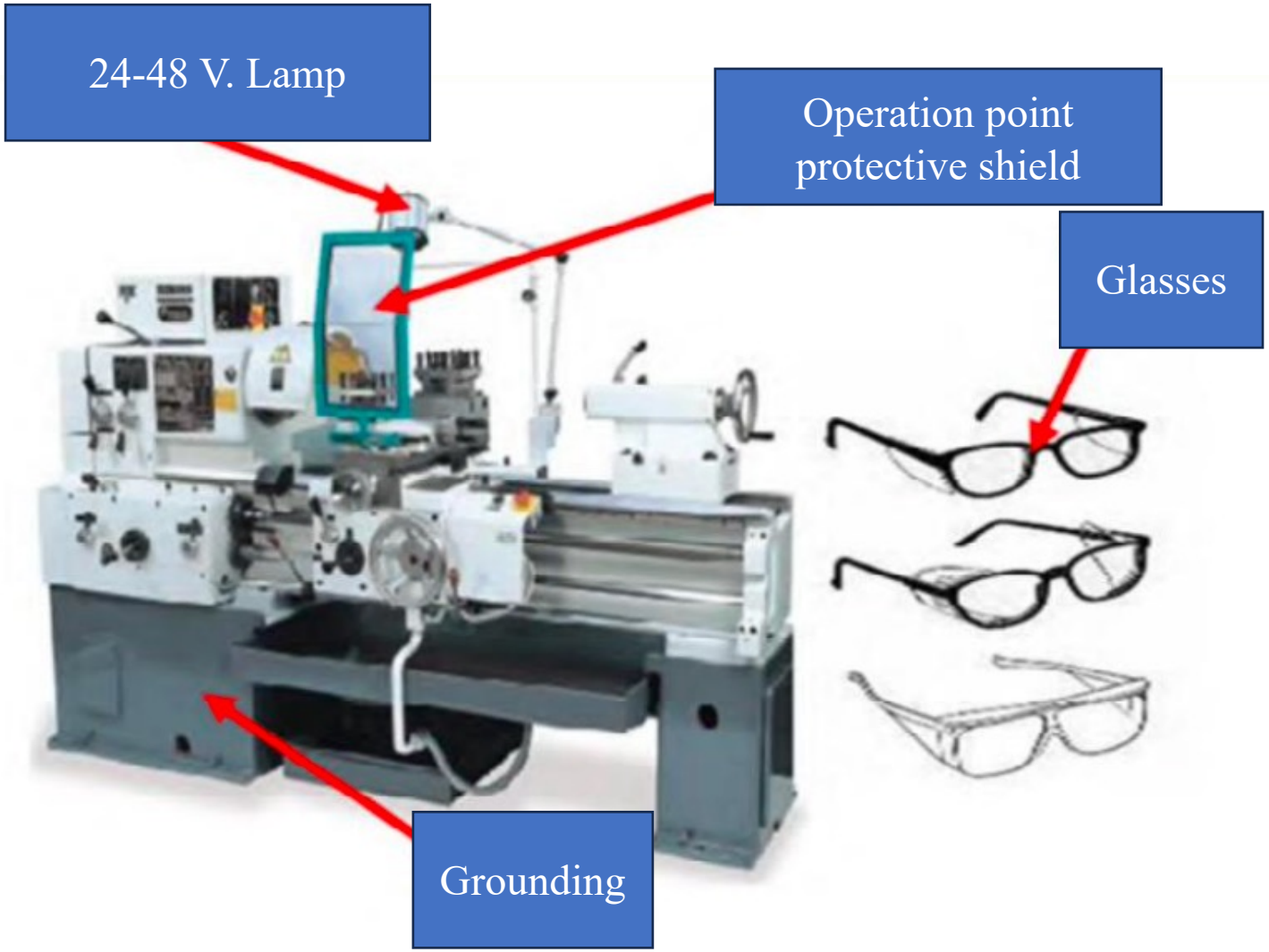


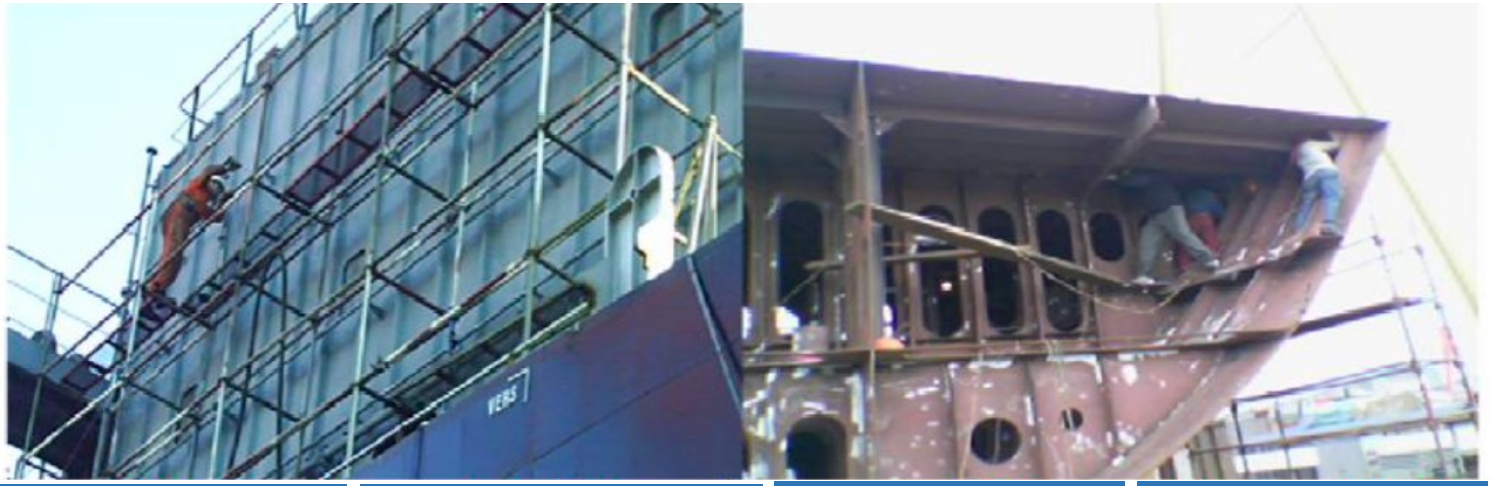
Risk Reduction – Here the risks are systematically reduced through control measures, according to the hierarchy of risk control described in earlier sections.

Danger, Risk, Lathe



Danger, Risk, Lathe, Precaution

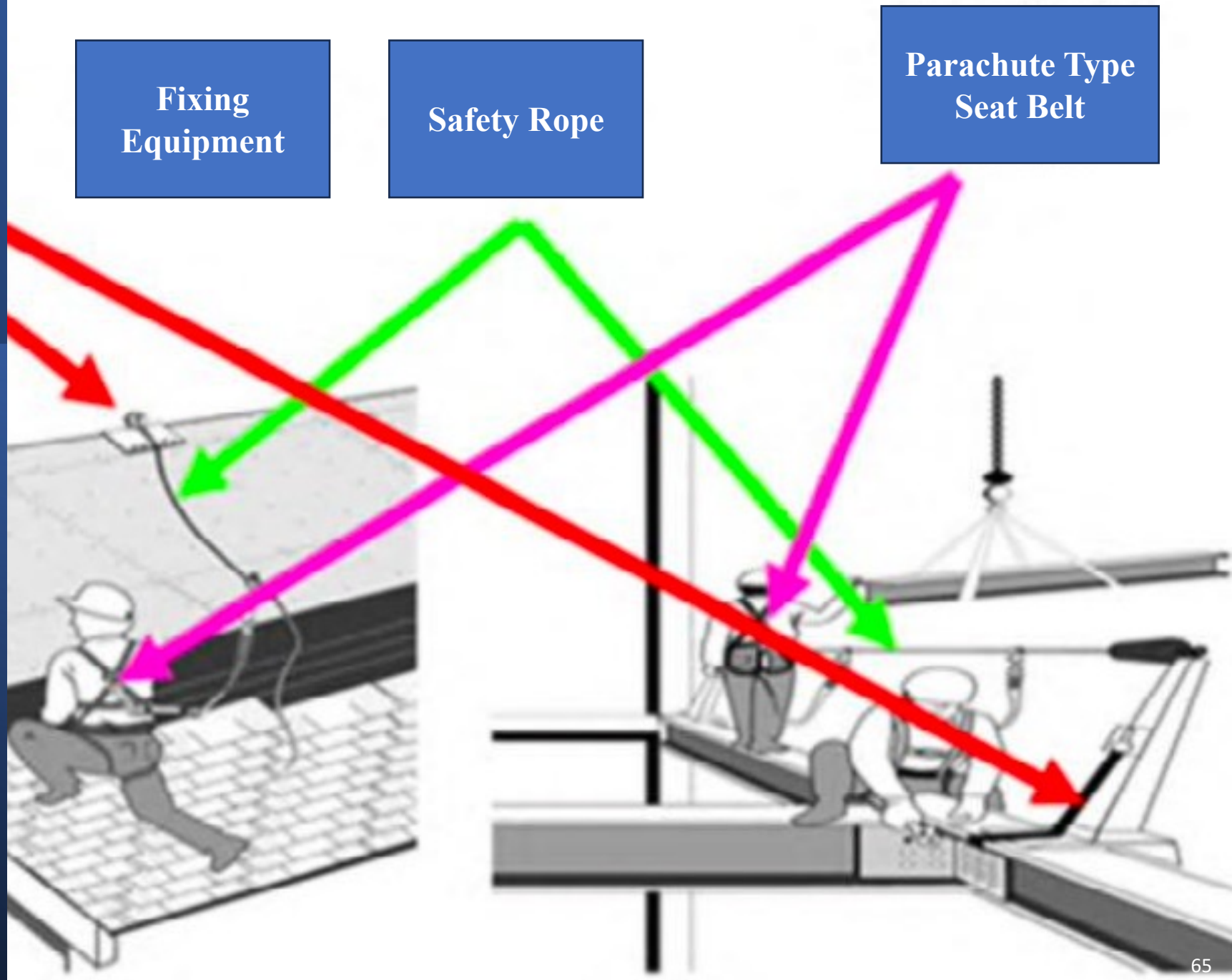




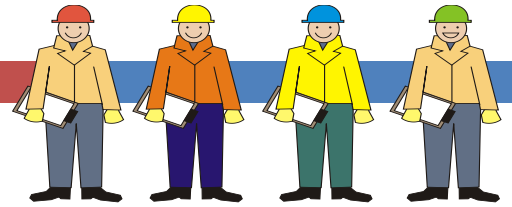
Source of Danger	Danger	Risk	Conclusion
Working at Height	Lack of Safety Ropes, Working Without a Seat Belt	Loss of Balance or Fall as a result of Slipping	Death or Serious Injury (permanent disability)

Danger, Risk, Working at Height

Danger, Risk, Working at Height, Precaution

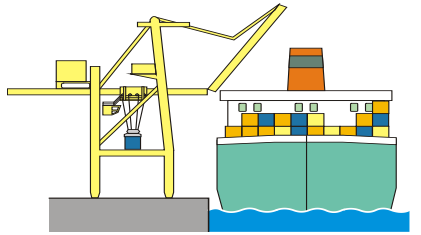


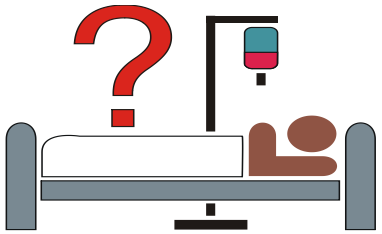
RISK MANAGEMENT FLOW



1. Assemble assessment team

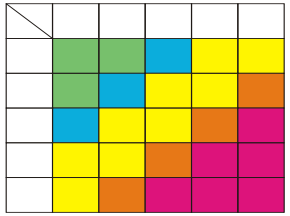
2. Visit site, and identify hazards





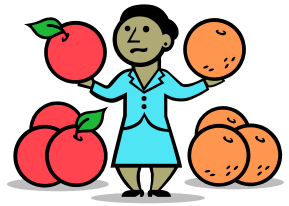
3. Evaluate severity of hazard (1 - 5)

4. Evaluate likelihood of occurrence (1 - 5)



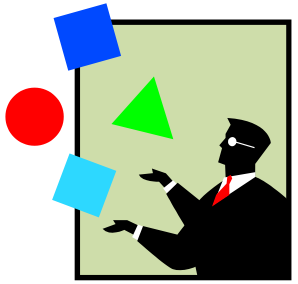
5. Combine severity + likelihood values to express RISK (1 - 25)

RISK MANAGEMENT FLOW



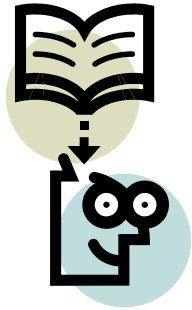
6. Compare rating with a criterion

7. Assign priorities



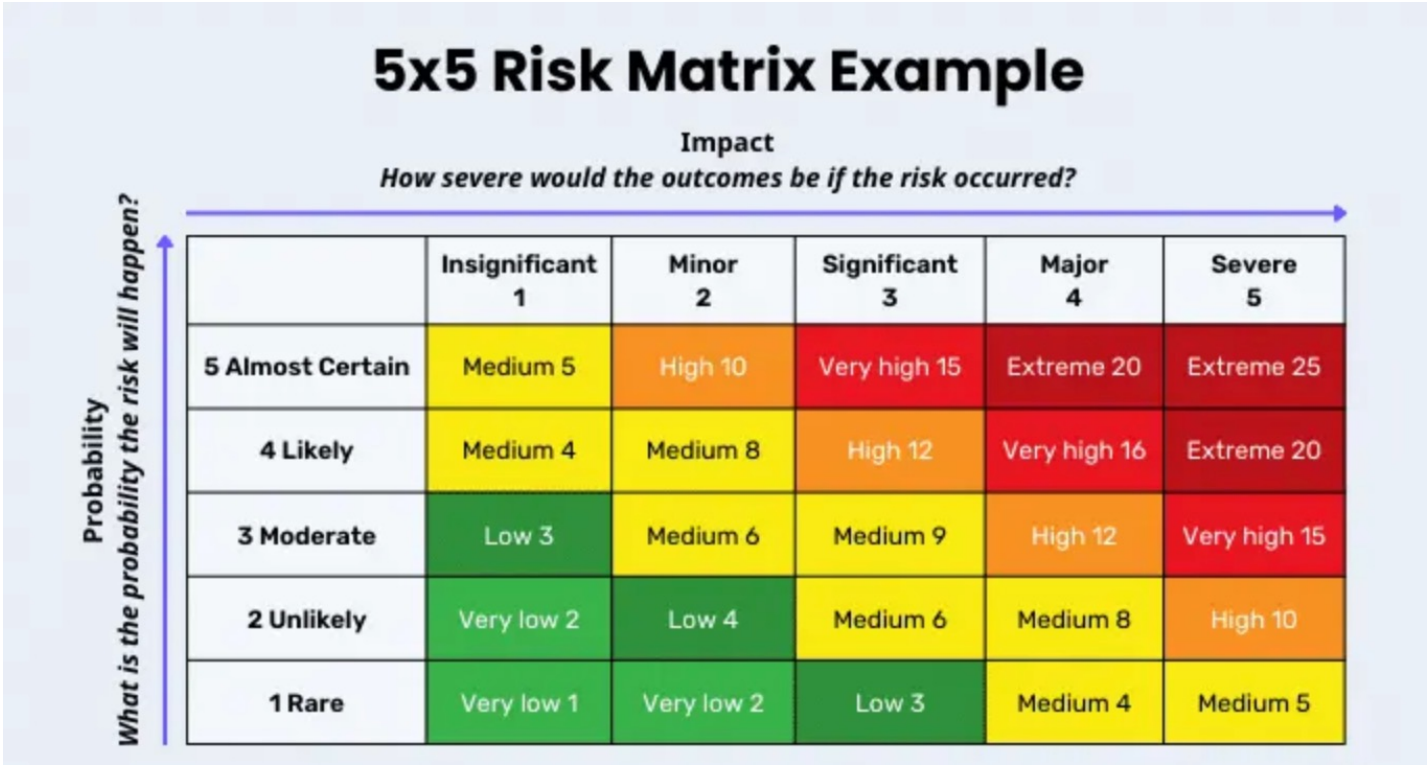
8. Implement Controls. Control Hierarchy.

9. Information to the workers



10. Monitoring and review

Risk Matrix



5x5 Risk Matrix Example

Impact

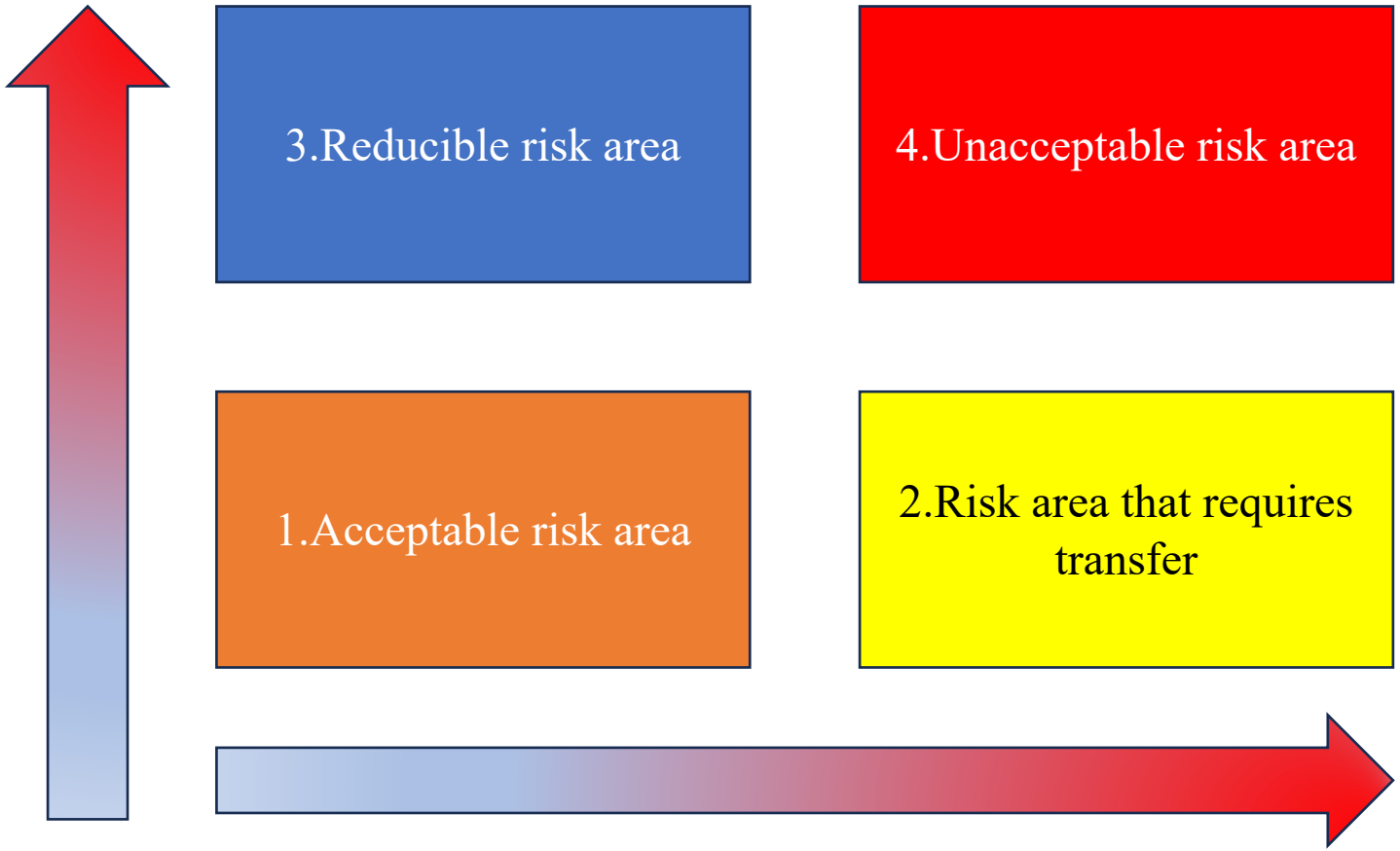
How severe would the outcomes be if the risk occurred?

What is the probability the risk will happen?

Probability

	Insignificant 1	Minor 2	Significant 3	Major 4	Severe 5
5 Almost Certain	Medium 5	High 10	Very high 15	Extreme 20	Extreme 25
4 Likely	Medium 4	Medium 8	High 12	Very high 16	Extreme 20
3 Moderate	Low 3	Medium 6	Medium 9	High 12	Very high 15
2 Unlikely	Very low 2	Low 4	Medium 6	Medium 8	High 10
1 Rare	Very low 1	Very low 2	Low 3	Medium 4	Medium 5

Risk Matrix Characteristics of Regions



Risk Assessment Methods

Selection of Risk Assessment Method

The selection stage of risk assessment methods in a business is the most important. Making this choice incorrectly will cause material and moral losses to the business.

When creating a risk map and performing an initial hazard analysis, the decision on which qualitative and quantitative methods to choose should be made by an expert in this field, according to the **business's own needs, structure and the magnitude of the hazards.**

Selection of Risk Assessment Method

Small organizations with small risks can be protected from complex and difficult dangers. Forcing identification, risk assessment and risk control practices will reduce the success rate.

In a business where risk assessment will be made, first of all, "Risk In order for the Management Process" to be established, the stages of the process must be well understood .

The "Hazard Identification" phase, which is the first phase of the "Risk Management Process", is the most important phase.

At this stage, it is necessary to apply a separation algorithm, create material safety forms , disassemble these forms and create transportation, storage, use and emergency action and first aid instructions, and hazard rating and classification.

Selection of Risk Assessment Method

- Risk assessment can only be done by one person/analyst in the business. It is not something you can do on your own.
- Even if there is only one OHS Specialist in the enterprise who deals with this job, it is a work that requires the active work of everyone in the enterprise, from the senior management staff to all the workers. (Everyone's participation)
- It should not be forgotten that; If the perspective of the business on this issue is only to fulfill a legal obligation , there will be no reduction in the rate of work accidents and occupational diseases or the severity of property damage in that business, and working day and financial losses will not be prevented.

Selection of Risk Assessment Method

- Informing the business before starting the risk assessment meetings should be held and training on the subject should be provided, and all employees in the business as well as the management staff should be included in this study.

- Data is absolutely necessary to accurately identify hazards and evaluate risks, and most of this data can be obtained from employees (near accident, dangerous situation, avoidance of work forms, accident/incident investigation reports).

- Especially regarding the situations found in the completed forms, the employee who fills out the information should be approached positively and work together to prevent the incident from recurring. An inquisitive approach will prevent this data from coming in and the analyst will lose the most important data source.

Selection of Risk Assessment Method

- In a business that will create a new "Risk Management Process", a "Risk Map" is first created.
- Hazards such as injury, slipping, falling, death, material falling, occupational disease, machinery-equipment damage, contact with chemical substances, fire, explosion etc. in the business/workplace are defined and "Risk Maps" and "Information Banks" of the workplace are created according to these definitions.
- Using the created knowledge banks, Equipment Surveillance Analysis, Equipment Behavior Analysis and Accident Scenario Result Algorithm are created, so that Accident Scenarios Knowledge Bank can be created.
- Establishing the Risk Management Process in a business with a risk map. It is much easier.

Risk Assessment Methods

Qualitative Risk Assessment Methods

Quantitative Risk Assessment Methods

Can Be Classified As Mixed Risk Assessment Methods

Qualitative Risk Assessment Methods

“Qualitative risk analysis uses descriptive values (such as low, high, very high) instead of numerical (quantitative) values when calculating and expressing the risk.”

Qualitative analysis analyzes the degree of potential effects of events and their likelihood of occurrence through scales consisting of words.

Qualitative Risk Assessment Methods

1. Preliminary Hazard Analysis (PHA)
2. Primary Risk Analysis Using Check-List (PRA – Preliminary Risk Analysis Using Check-List)
3. What If? (What If?)
4. Hazard and Operability Analysis (HAZOP, Hazard and Operability Studies)

Preliminary Hazard Analysis (PHA)

For analysis of hazards during the design phase of the business – facility. It is the hazard assessment technique used.

- It is a qualitative risk assessment methodology that can be prepared quickly and can be used as a model for more detailed studies.
- In this method, possible **undesirable events** are first identified and then resolved separately. For each adverse event or hazard, possible improvements and preventive measures are formulated.
- The result from this methodology determines what types of hazards occur frequently and what analysis methods need to be applied.
- The identified hazards are listed with the help of the frequency/consequence diagram and measures are taken in order of priority.

Preliminary Hazard Analysis (PHA)

- PHA is applied by analysts at the early design stage, but it is not a sufficient analysis method on its own, it is useful as a starting data for other methodologies.
- Especially in cases where there are dangerous substances in the workplace/ enterprise or a process or system with a high degree of danger, it may be decided that "Safety Measurement Request for Process Industries" should be applied at the primary hazard analysis stage.
- While performing PHA, past experience analysis is made by taking into account past accidents and, if applicable, dangerous situations and near-accidents .
- This stage is very important because it plays a big role in deciding which methodologies to use. Past experience analysis provides data to the analyst about which errors mostly occur in the business.

Preliminary Hazard Analysis (PHA)

The next step is goal analysis, at this stage the desired goals are determines.

At the stage of hazard identification; Potentially dangerous elements, dangerous situations, dangerous events, safety system losses are used as data. If the business has no hazardous situation and past accident records, or is a newly established business, accident examples from businesses in the same business line can be used as data;

The experience of the analyst is of great importance at this stage.

The next step after identifying the hazards is to decide which risk assessment methods to choose. Risk score is determined according to the frequency and severity of the identified potential hazards using the "Preliminary Hazard Analysis Risk Rating and Selection Diagram" .

One thing to consider here is that violence is evaluated as “catastrophic”, “dangerous”, “marginal” and “unimportant” .

Preliminary Hazard Analysis (PHA)

- If a risk score in unacceptable regions is obtained as a result of the risk assessment , it means that the control measures taken to protect the mechanical integrity of the process/business are not sufficient to reduce the danger potential.

- In this case, it is stated as a corrective measure that a “Security Integrity Degree” should be assigned to the “Security Measurement request”.

Preliminary Hazard Analysis (PHA), Risk Assessment Selection Table

Risk Assessment 5 x 5 Matrix					
Risk Likelihood	Severity				
	Catastrophic A	Critical B	Moderate C	Minor D	Negligible E
5 - Frequent	5A	5B	5C	5D	5E
4 - Likely	4A	4B	4C	4D	4E
3 - Occasional	3A	3B	3C	3D	3E
2 - Seldom	2A	2B	2C	2D	2E
1 - Improbable	1A	1B	1C	1D	1E

Risk Likelihood Definitions		
Likelihood	Chance of event	Value
Frequent	1 in 100	5
Likely	1 in 1,000	4
Occasional	1 in 10,000	3
Seldom	1 in 100,000	2
Improbable	1 in a million	1

Assessment Values	Meaning	Accountable Organizations
5A, 5B, 5C, 4A, 4B, 3A	Unacceptable - requires immediate action.	Risk Review Board and VPs of relevenant departments.
5D, 5E, 4C, 3B, 3C, 2A, 2B	Manageable under risk control and mitigation.	Managing Directors and Risk Review Board.
4D, 4E, 3D, 2C, 1A, 1B	Acceptable after review of the operation. Continued tracking and recorded action plans are required.	Managing Directors and relevant organization levels.
3E, 2D, 2E, 1C, 1D, 1E	Acceptable - continued data collection and analysis for improvement is required.	Department Managers and relevant organization levels.

Severity of Occurrences						
Severity	Impact to...					Value
	Personnel Safety	Resources	Work Performance	Property Damage	Reputation	
Catastrophic	Multiple deaths	Institutional resources required	System-wide shutdown Operation suspension	Large environmental impact Equipment destroyed	Uncontrollable public relations events	A
Critical	Serious injury or death	Institutional resources required	Major operational disruptions	Medium environmental impact Moderate equipment damage	Loss of confidence	B
Moderate	Moderate to life impacting injuries	Additional resources required	Significant delays	Small environmental impact	Damaged	C
Minor	Minor injuries	Moderate impact	Modest delays	No environmental impact Slight equipment damage	Potential damage	D
Negligible	No injuries	No impact	No delays	Minor	No impact	E

Failure Modes and Effect Analysis

The system is divided into sub systems that can be handled effectively. It involves:

- Identification of the component and parent system.
- Failure mode and cause of failure.
- Effect of the failure on the subsystem or system.
- Method of detection and diagnostic aids available.

Failure Modes and Effect Analysis

A typical format:

Component Function
Failure Mode
Failure Rate
Faileure Effect
Criticality

Detection Method

Preventative Measures

Failure Modes and Effect Analysis

- For each component's functions, every conceivable mode of failure is identified and recorded.
- It is also common to rate the failure rate for each failure mode identified.
- The potential consequences for each failure must be identified along with its effects on other equipment, components within the rest of the system.
- It is then necessary to record preventative measures that are in place or may be introduced to correct the failure, reduce its failure rate or provide some adequate form of detection.

Item	Component (function)	Failure modes	Failure effects	Failure detection method	Risk assessment		
					Severity category	Probability level	RPC*
1.0	Thermostat (switches gas valve to closed when water temperature reaches preset level)	Failure which closes gas valve	No gas supply to burners	Observation (of burners)	I	B	3
		Failure which opens gas valve	Water boils, boiler explodes	Hearing (sound of water boiling)	III	B	1
				Touch (temperature of casing)			
2.0	Gas valve (controls flow of gas to burners – on or off)	Crack in valve casing	Gas release	Observation (smell of gas)	IV	D	2
		Fails with valve closed	No gas supply to boiler	Observation (of burners)	I	D	3
		Fails with valve open	Water boils, boiler explodes	Observation (of burners)	III	D	3
				Hearing (sound of water boiling)			
				Touch (temperature of casing)			
3.0	Thermo-couple (closes gas valve when pilot light is extinguished)	Failure which closes gas valve	No gas supply to burners	Observation (of burners)	I	A	3
		Failure which opens gas valve	Water boils, boiler explodes	Hearing (sound of water boiling)	III	A	1
				Touch (temperature of casing)			
4.0	Water pump	Cracks in seal	Water in casing	Observation	I	B	3
		Fails open	Water runs continuously	Observation	II	D	3
		Fails closed	No hot water supply	Observation	I	D	3

FMEA no.		Failure Modes and Effects Analysis	Page of
Project no.			Date
System	Boiler		Prepared by
Subsystem		* RPC = Risk Priority Code 1 = High, 2 = Medium, 3 = Low	Evaluated by

Failure Modes and Effect Analysis

Failure Modes and Effect Analysis

Although FMEA is a time-consuming process, it is widely used because of its effectiveness in identifying hazards and risks associated with component failures. The data it provides can also be used as a basis for the advanced risk assessment techniques described next – Event Tree Analysis and Fault Tree Analysis

Item	Component	Failure mode	RPC*	Action required/remarks
1.0	Thermostat	Failure which opens gas valve	1	Design change. Any failure in the thermostat should result in the gas valve being closed
2.0	Thermocouple	Failure which opens gas valve	1	Design change. Any failure in the thermocouple should result in the gas valve being closed
3.0	Gas valve	Crack in valve casing	2	Design change. Review probability of valve case cracking to probability level E

FMEA no.		FMEA Summary	Page of
Project no.			Date
System	Boiler		Computers
Subsystem		* RPC = Risk Priority Code 1 = High, 2 = Medium, 3 = Low	

Sample FMEA summary sheet for a domestic gas boiler

Hazard & Operability Studies

- Hazard and Operability studies (HAZOPs) are primarily used in the design stage to identify hazards which could occur if the process or operation did not go as planned – in other words, the hazards arising from failures or malfunctions in the system. However, HAZOPs can be used for existing systems.
- HAZOP is a qualitative procedure which systematically examines a process by asking questions about what could go wrong. It is generally carried out by a small team of people with knowledge of the system, directed by a group leader experienced in HAZOP.

Hazard &Operability Studies

- Hazard and Operability Studies(HAZOP)have been used for many years as a formal means for the review of chemical process designs.
- A HAZOP study is a systematic search for hazards which are defined as deviations within these parameters that may have dangerous consequences.
- In the process industry, these deviations concern process parameters such as flow, temperature, pressure etc.

Hazard & Operability Studies

- HAZOP is a team approach, involving a team of people representing all different functions in a plant.
- They identify all the deviations by ‘brain-storming’ to a set of guide words which are applied to all parts of the system.

Hazard & Operability Studies

The process is as follows:

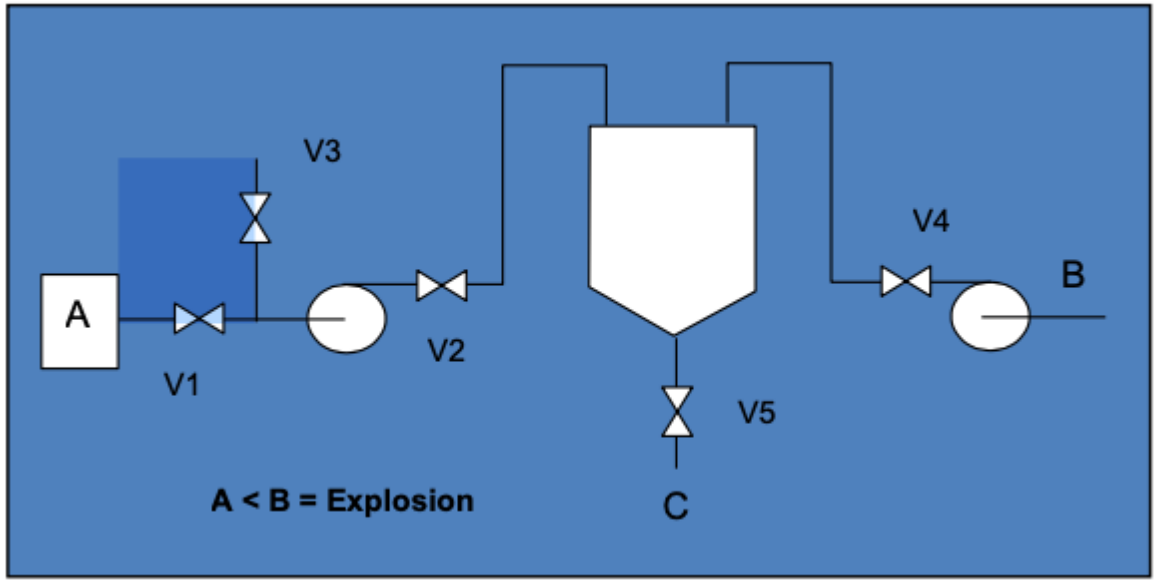
- The system is divided into suitable parts or sub-systems, which are then analysed one at a time.
- For each sub-system each parameter (flow, temperature, pressure, volume, viscosity etc.) that has an influence on it, is noted.
- Guidewords are applied to each parameter in each subsystem. The intention is to prompt creative discussion of deviations and possible consequences
- For each significant deviation, possible causes are identified.

Hazard & Operability Studies

Guideword	Definitions
NO or NOT	No part of the design intent occurs, such as no flow in a pipeline due to blockage.
MORE or LESS	A quantitative increase or decrease of some parameter, such as flow, temperature etc.
AS WELL AS	All the design intentions are fulfilled and something happens in addition
PART OF	Only part of the design intention is fulfilled
REVERSE	The logical opposite of the design intention occurs
OTHER THAN	Something completely different than attended occurs

Hazard & Operability Studies
Example

Consider the simple process diagram below. It represents a plant where substances A and B react with each other to form a new substance C. If there is more B than A there may be an explosion.



Example from Harms Ringdahl L (1995), Safety Analysis: Principals and Practice in Occupational Safety, Elsevier Applied Science.

Hazard & Operability Studies
Example

The HAZOP sheet for the section of the plant from A to C will be as follows:

Guide Word	Deviation	Possible Causes	Consequences	Proposed Measures
NO, NOT	No A	Tank containing A is empty. V1 or V2 closed. Pump does not work. Pipe broken	Not enough A = Explosion	Indicator for low level. Monitoring of flow
MORE	Too much A	Pump too high capacity Opening of V1 or V2 is too large.	C contaminated by A. Tank overfilled.	Indicator for high level. Monitoring of flow
LESS	Not enough A	V1,V2 or pipe are partially blocked. Pump gives low flow or runs for too short a time.	Not enough A = Explosion	See above
AS WELL AS	Other substance	V3 open – air sucked in	Not enough A = Explosion	Flow monitoring based on weight
REVERSE	Liquid pumped backwards	Wrong connector to motor	Not enough A = Explosion A is contaminated	Flow monitoring
OTHER THAN	A boils in pump	Temperature too high	Not enough A = Explosion	Temperature (and flow) monitoring.

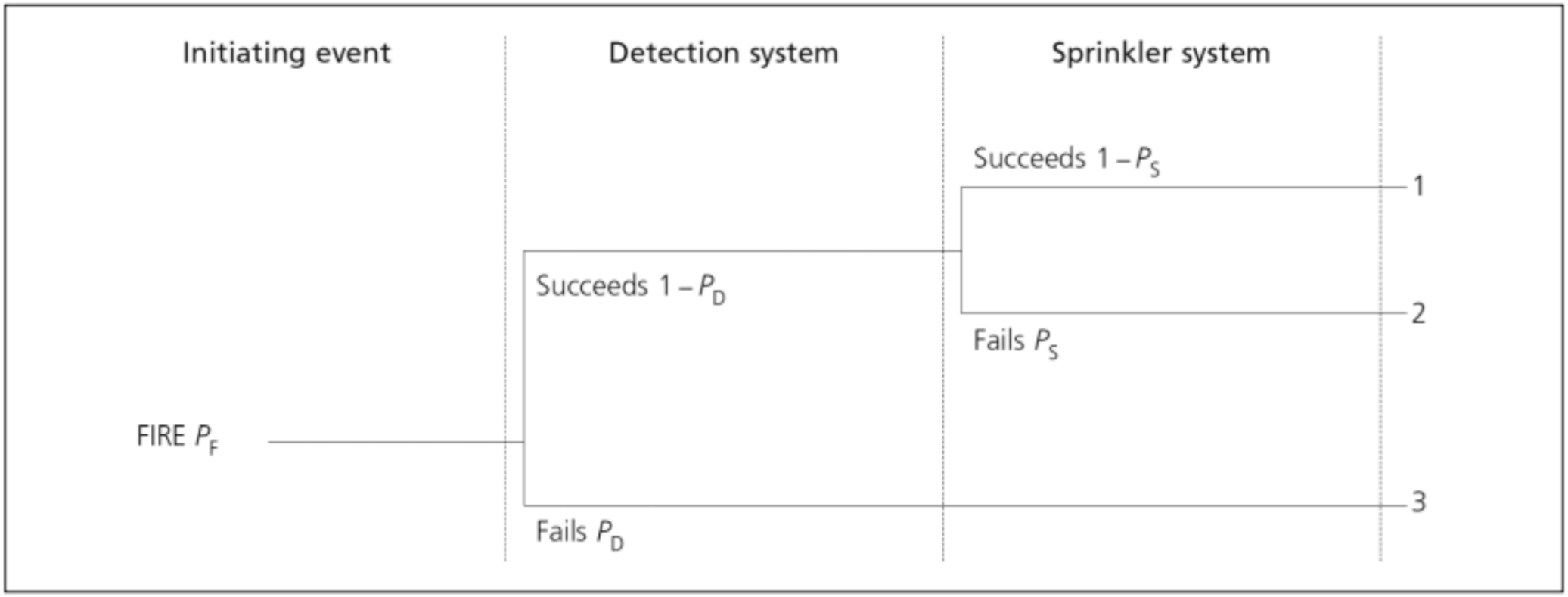
Example from Harms Ringdahl L (1995), Safety Analysis: Principals and Practice in Occupational Safety, Elsevier Applied Science.

Domestic gas boiler — to provide hot water on demand				
Guide word	**Deviation**	**Possible causes**	**Consequences**	**Action required**
No	Gas pressure	Supply failure Pipe rupture Pipe blocked Valve failure	Pilot light goes out	Mechanism to prevent gas flowing while pilot light is out (thermocouple) (Possible causes may be outside system)
More		Error by supplier	Pilot light extinguished Too rapid combustion	As above Check effects
No	Level (of water in boiler)	Leaks Supply failure	Overheating	Mechanism to shut down burners if there is no water in boiler
More	Temperature (of water in boiler)	Burner runs for too long	Water boils Pressure build-up Rupture of boiler	Mechanism to shut off burners when water temperature reaches required level (thermostat) Pressure release valve on boiler?
No	Flow (of oxygen into system)	Blocked vents	Pilot light goes out	Mechanism to stop vents being blocked Thermocouple
Less		As above	Partial combustion, carbon monoxide emission	Vent all exhaust gases to atmosphere
As well as		Dusts, other gases in air flow	Depend on dusts, gases	Investigate area for possible dusts, gases
More	Pressure (in boiler)	Boiling of water	Rupture of boiler	Pressure release valve
Reverse		Condensation in steam-filled boiler	Implosion of boiler	Determine required specification for boiler casing
No	Ignition (of gas by pilot light)	Pilot light extinguished Gas pressure too high	Unignited gas in casing	Thermocouple, adequate venting Regulator valve
As well as		Human intervention (match or taper)	Explosion	No entry point in casing for external ignition sources Internal ignition source required (igniter)

Partial HAZOP for a domestic gas boiler

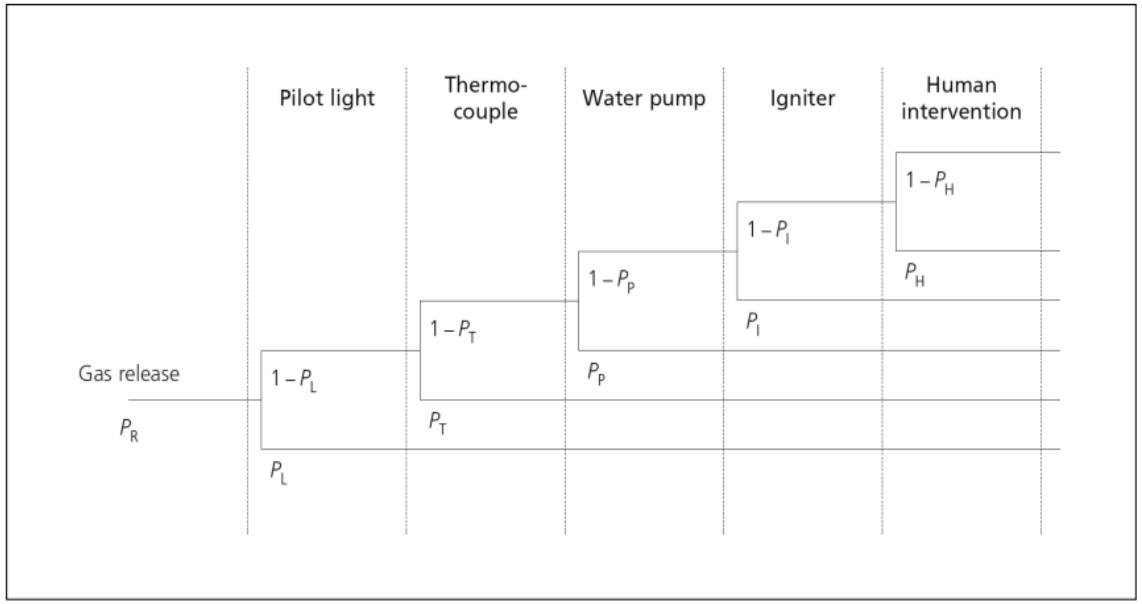
Event Tree Analysis

Event Tree Analysis(ETA) is primarily used to analyse the possible effects and consequences of a failure, unlike HAZOP and FMEA, which are primarily used to identify hazards.



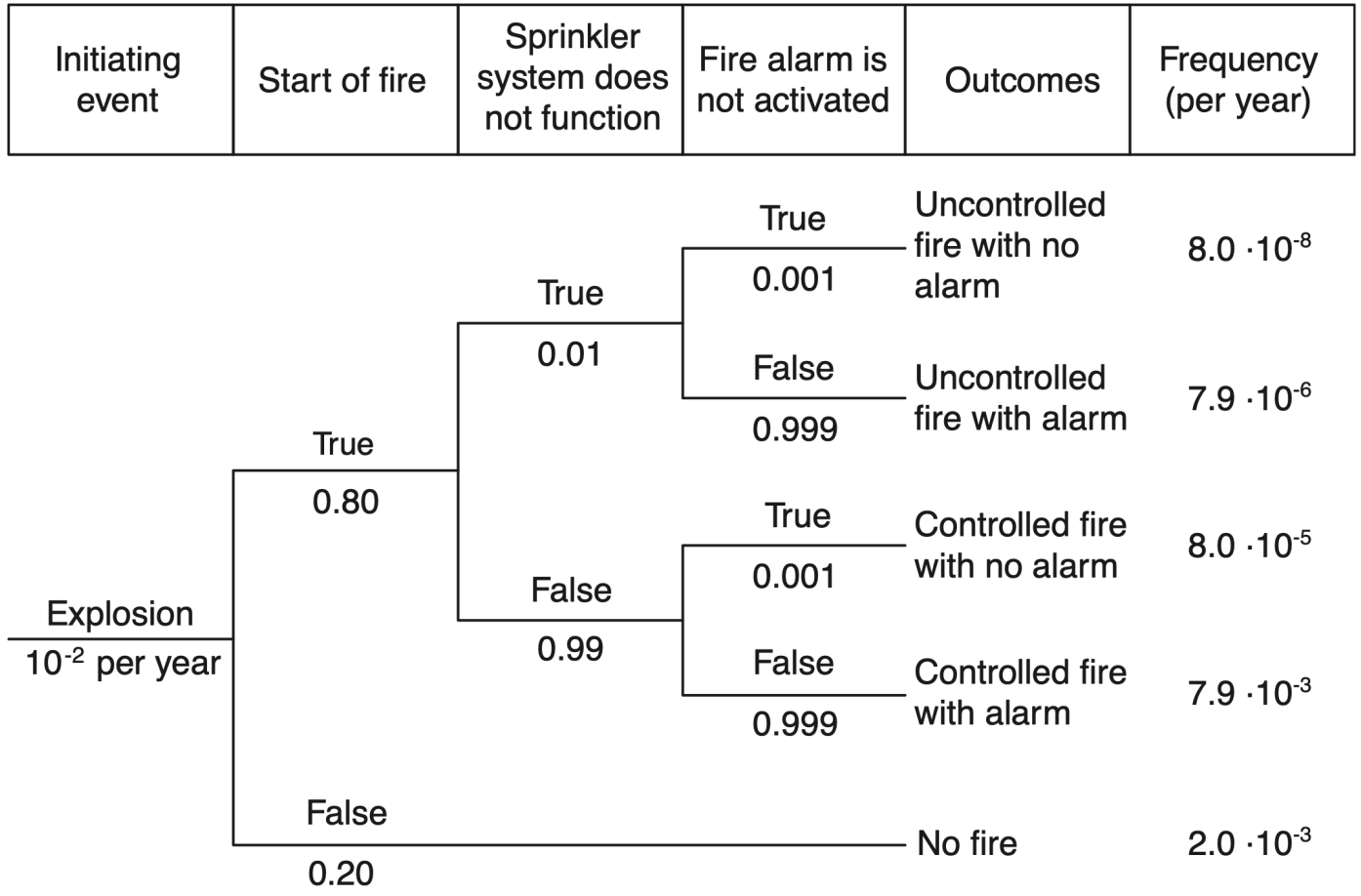
Event Tree Analysis

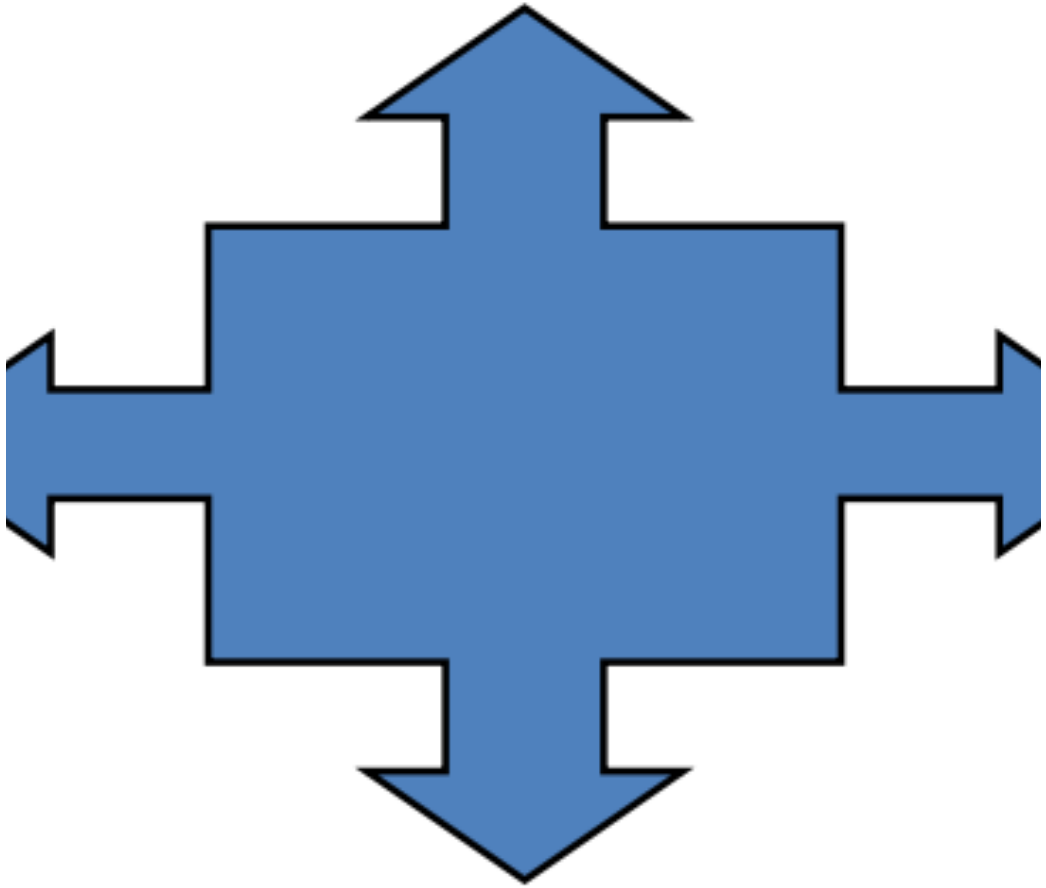
- Simplified Event Tree Analysis Diagram



Event Tree Analysis Partial ETA for a Domestic gas boiler

Event Tree Analysis Partial ETA for starting fire





Fault Tree Analysis

- A fault tree is a diagram that displays the logical interrelationship between the basic causes of the hazard.

- Fault tree analysis can be simple or complex depending on the system in question. Complex analysis involves the use of Boolean algebra to represent various failure states.

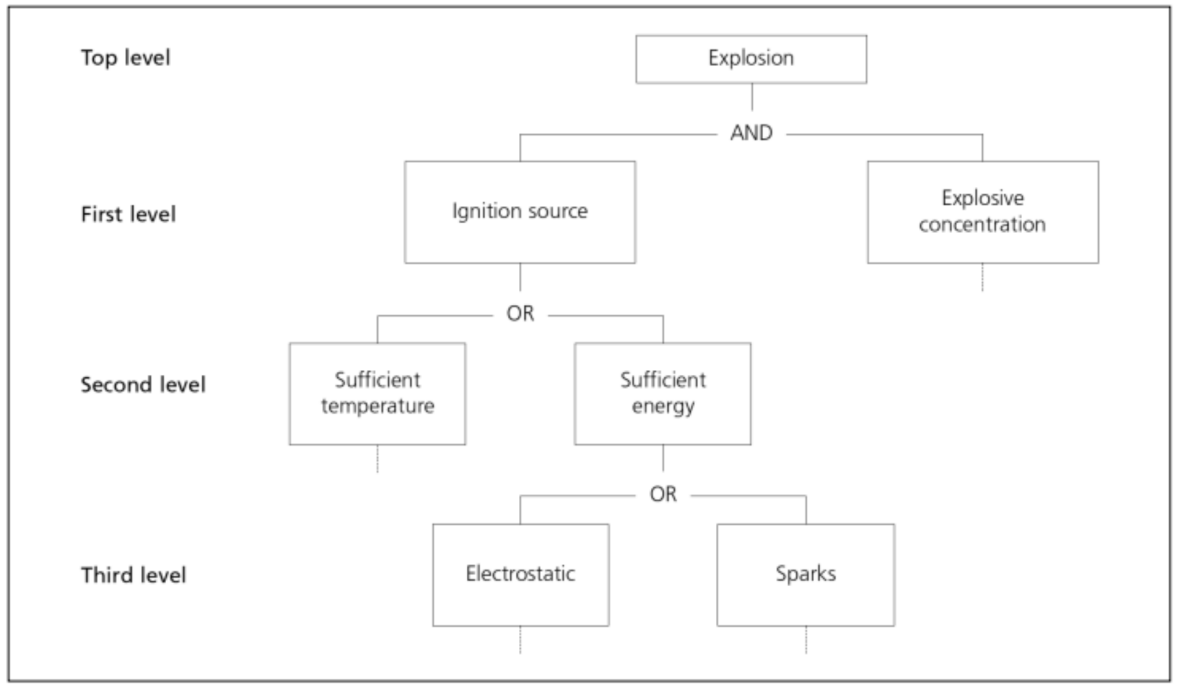
Fault Tree Analysis

- The first stage is to select the hazard or top event that is to be analysed.
- The tree is structured so that the hazard appears at the top. It is then necessary to work downwards, firstly by identifying causes that directly contribute to this hazard.
- When all the causes and sub causes have been identified, the next stage is to construct the fault tree.

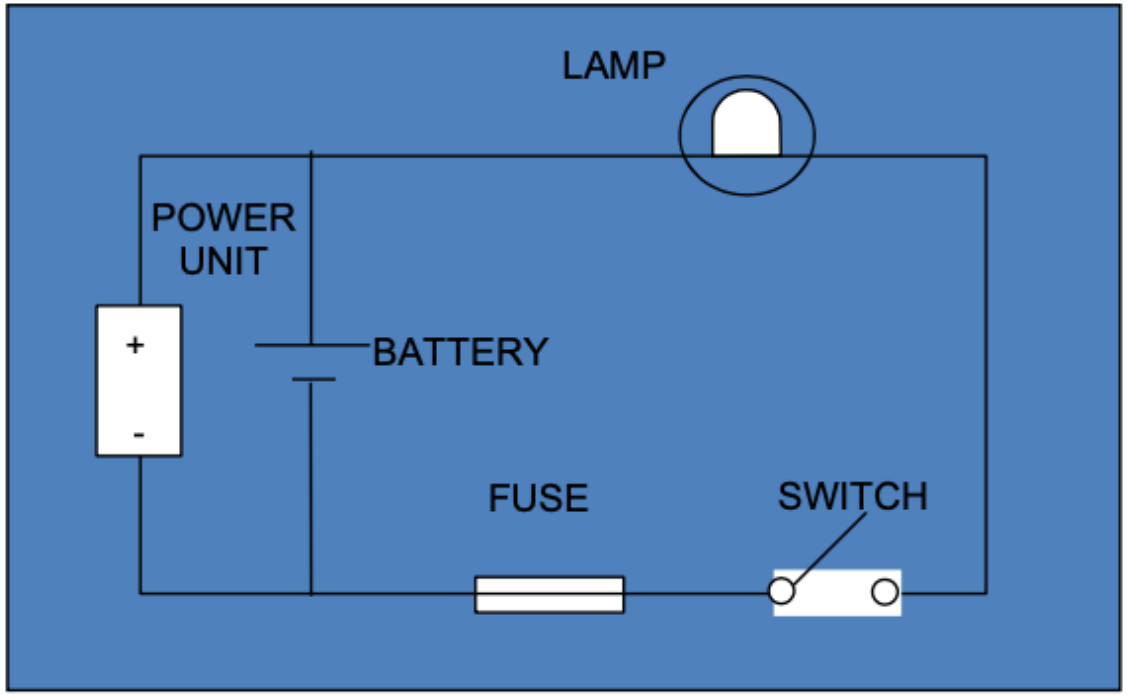
Fault Tree Analysis

Symbol	Designation	Function
	EVENT / CAUSE	Causes or events that can be developed further
	BASIC EVENT/CAUSE	Basic or Root Causes or events that cannot be developed further
	UNDEVELOPED EVENT/CAUSE	Causes are not developed due to lack of information or significance.
	AND gate	Output event occurs only if all input events occur
	OR gate	Output event occurs if any one of the input events occurs

Simplified fault tree



Fault Tree Analysis

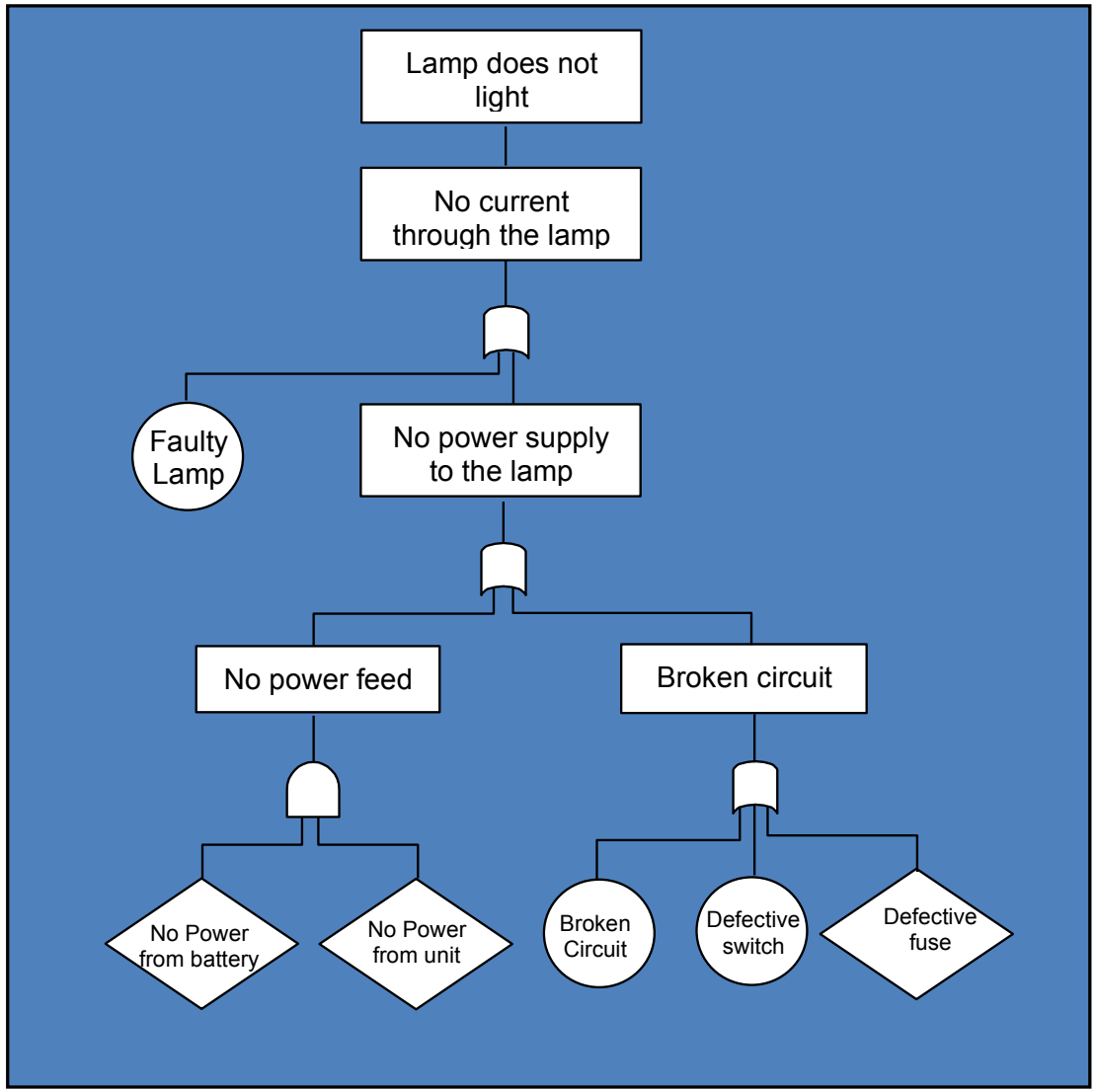


Consider the simple circuit diagram shown in figure.

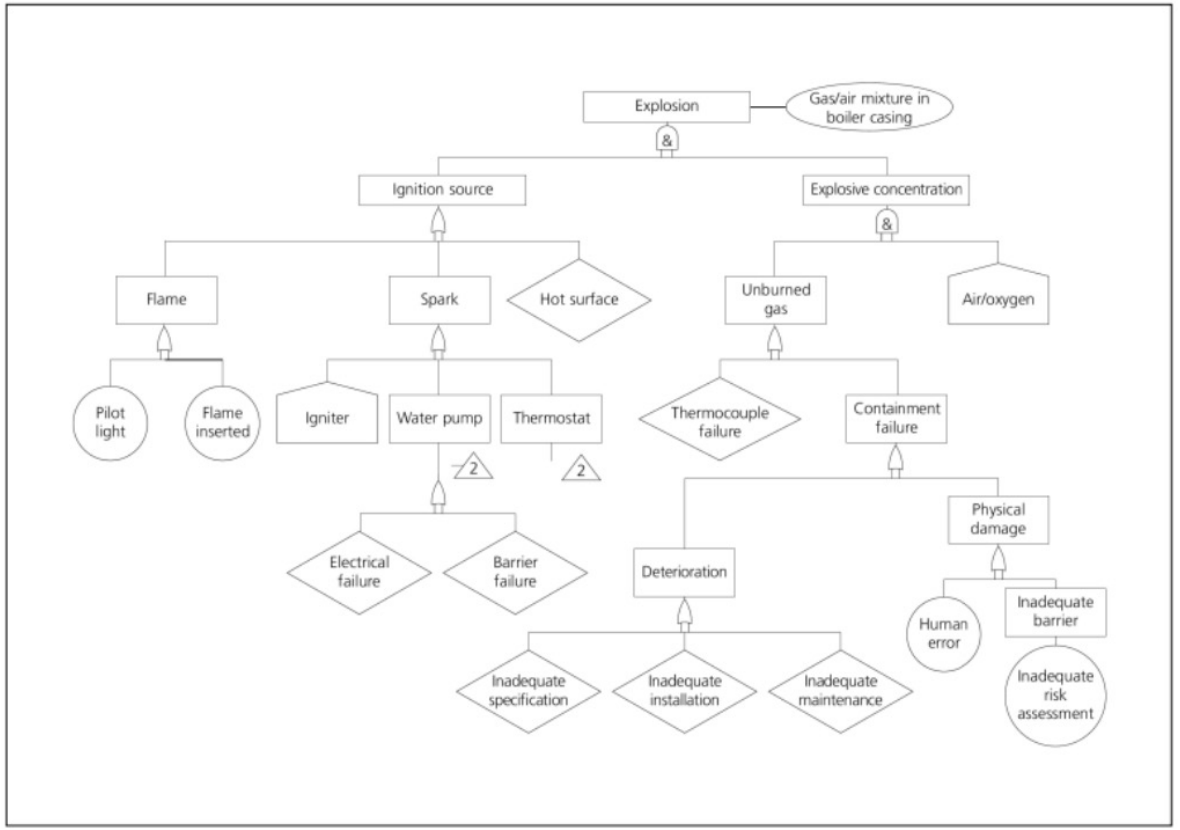
Example from Harms Ringdahl L (1995), Safety Analysis: Principals and Practice in Occupational Safety, Elsevier Applied Science.

Fault Tree Analysis

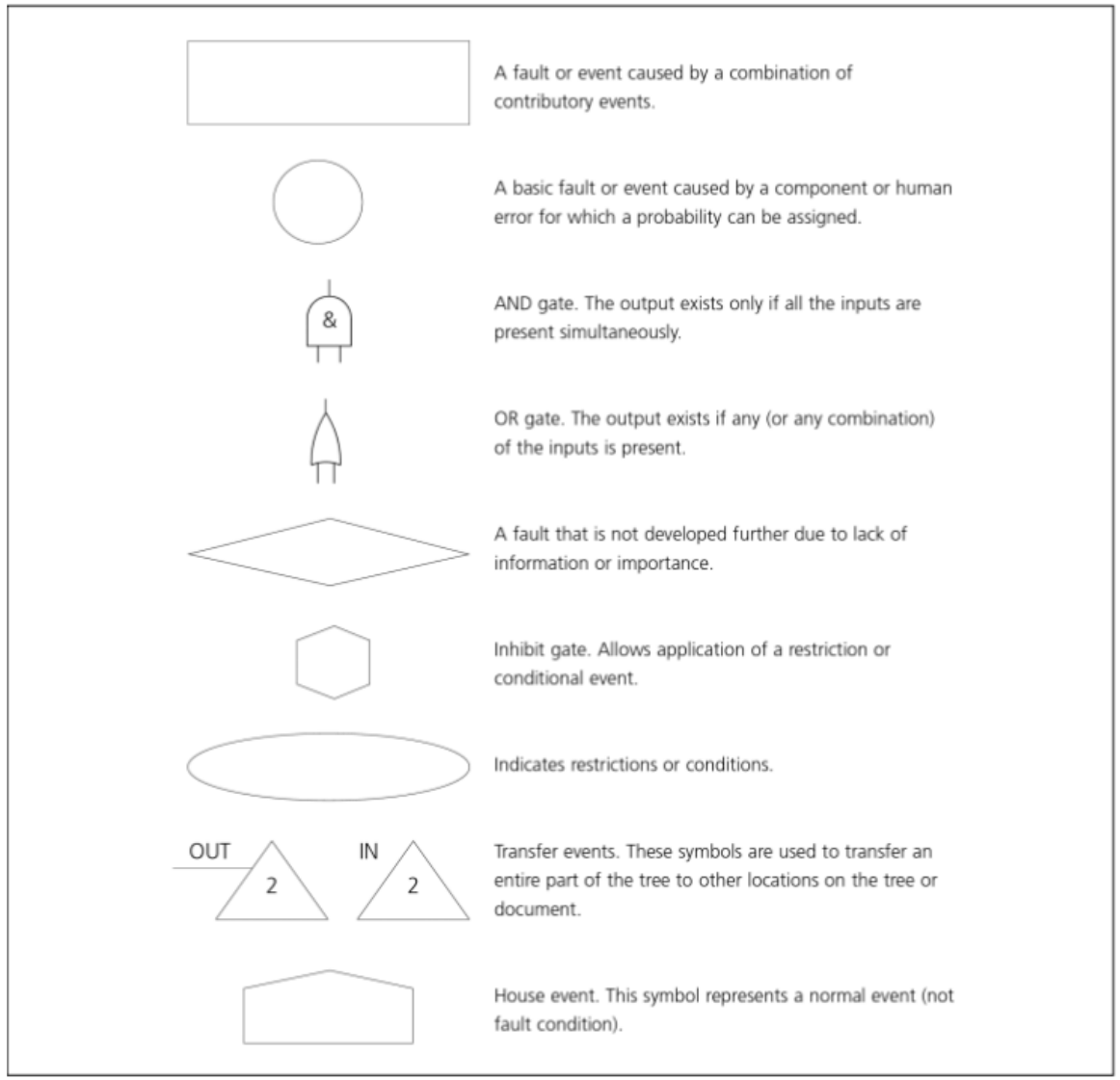
- The corresponding fault tree for the above circuit, with the top event (or hazard) being the lamp not working is as follows:



Partial FTA for an explosion in a domestic gas boiler casing



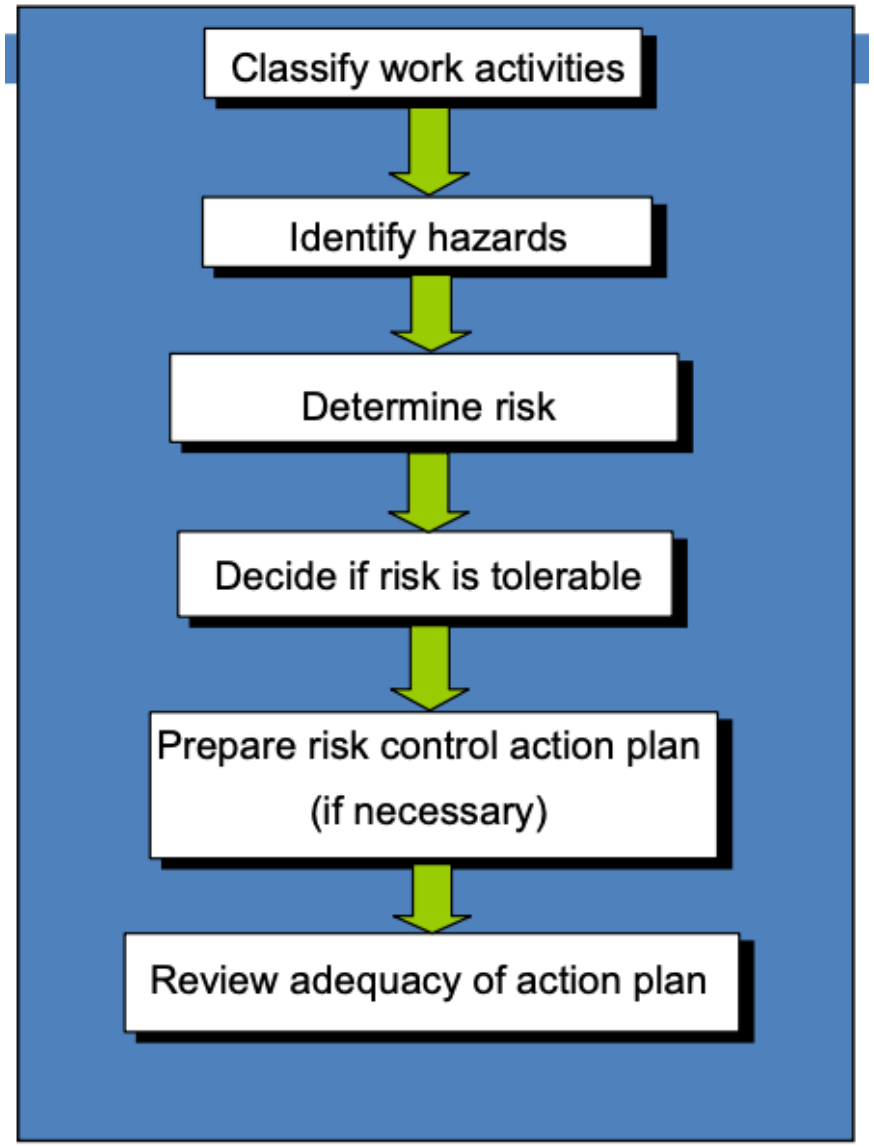
Sample of FTA symbols



Fault Tree Analysis

- Fault trees can be analysed qualitatively and quantitatively, depending on the data available.
- Where information is available on the probabilities of basic causes, it is possible to carry out a quantified analysis of the fault tree and arrive at an estimate of the probability of the top event.

Practical Risk Assessment



Classify Work Activities

- Possible ways of classifying work activities include:
- Geographical areas within/outside the organisation's premises.
- Stages in the production process, or in the provision of a service.
- Planned and reactive work.
- Defined tasks (e.g. driving).

Identify Hazards

- ***Broad categories of hazard***

To help with the process of identifying hazards it is useful to categorise hazards in different ways, for example by topic, e.g.:

- Mechanical.
- Electrical.
- Radiation.
- Substances.
- Fire and explosion.

Hazards prompt-list

- *During work activities could the following hazards exist?*
- *Slips/falls on the level.*
- *Falls of persons form heights.*
- *Falls of tools, materials, etc., from heights.*
- *Inadequateheadroom.*
- *Hazards associated with manual lifting/handling of tools, materials, etc..*
- *Hazards from plant and machinery associated with assembly, commissioning, operation, maintenance,*
- *modification, repair and dismantling.*

Hazards prompt-list

- *Vehicle hazards, covering both site transport, and travel by road.*
- *Fire and explosion.*
- *Violence to staff.*
- *Substances that may be inhaled.*
- *Substances or agents that may damage the eye.*
- *Substances that may cause harm by coming into contact with, or being absorbed through, the skin.*
- *Substances that may cause harm by being ingested (i.e., entering the body via the mouth).*
- *Harmful energies (e.g., electricity, radiation, noise, vibration).*

Hazards prompt-list

- *Work-related upper limb disorders resulting from frequently repeated tasks.*
- *Inadequate thermal environment, e.g. too hot.*
- *Lightinglevels.*
- *Slippery, uneven ground/surfaces.*
- *Inadequate guard rails or hand rails on stairs.*
- *Contractors'activities.*