Health and Safety Essentials

Lecture 15 - Risk Assessment Methodologies

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Undergraduate Diploma in
Occupational Health and Safety

Objectives of the Lecture

By the end of this lecture, you will be able to:

- Understand the principles and importance of risk assessment.
- Differentiate between various risk assessment methodologies.
- Apply a selected methodology to a case study.

✅ Recap Question 1

Which statement BEST distinguishes risk assessment from emergency planning?

- A. Risk assessment and emergency planning are essentially the same process
- B. Risk assessment focuses only on legal compliance, while emergency planning focuses on training
- C. Risk assessment aims to prevent adverse events, whereas emergency planning focuses on mitigating their consequences if they occur
- D. Emergency planning replaces the need for risk assessment

✅ Recap Question 2

According to ISO 45001, a potential emergency situation is BEST described as:

- A. Any workplace hazard identified during routine inspection
- B. A scheduled safety drill or planned maintenance shutdown
- C. An unplanned or unscheduled situation requiring immediate response to prevent harm
- D. A minor incident that does not require external support

✅ Recap Question 3

Which of the following is MOST critical during an emergency event?

- A. Maintaining normal production targets
- B. Completing documentation before taking action
- C. Protecting company reputation
- D. Preservation of life and personal safety

History of Risk Assessment

- Probabilistic risk assessment as we know it today had its root in the insurance (actuarial) discipline at the end of the nineteenth century.

- The Swedish actuary Filip Lundberg is considered to be the founder of mathematical risk theory. His first mathematical model for nonlife insurance was presented already in 1909.

- Was largely ignored till the Swedish professor Harald Cramér in 1930 developed his insurance risk theory (based on Lundberg's approach.

What is Risk Assessment?

EU-OSHA Definition

- Risk assessment is the process of evaluating risks to workers' safety and health from workplace hazards. It is a systematic examination of all aspects of work that considers:

  - what could cause injury or harm;
  - whether the hazards could be eliminated and, if not;
  - what preventive or protective measures are, or should be, in place to control the risks.

https://oira.osha.europa.eu/en/what-is-risk-assessment

Other definitions

- Hazards
  - A hazard can be anything - whether work materials, equipment, work methods or practices - that has the potential to cause harm.

- Risks
  - A risk is the chance, high or low, that somebody may be harmed by the hazard.

Why is Risk Assessment Important?

- ✅ Prevents workplace injuries and illnesses.
  ✅ Ensures legal compliance (EU & UK).
  ✅ Improves workplace safety culture.
  ✅ Supports effective risk management.

- 💬 Discussion Question:
  Why is risk assessment a core element of OHS?

Legal Frameworks

📜 EU & Maltese Legislation:

- Framework Directive 89/391/EEC (Employers must conduct risk assessments).
- Maltese OHS Act (CAP. 646) (Transposes EU laws).

📜 UK Legislation:

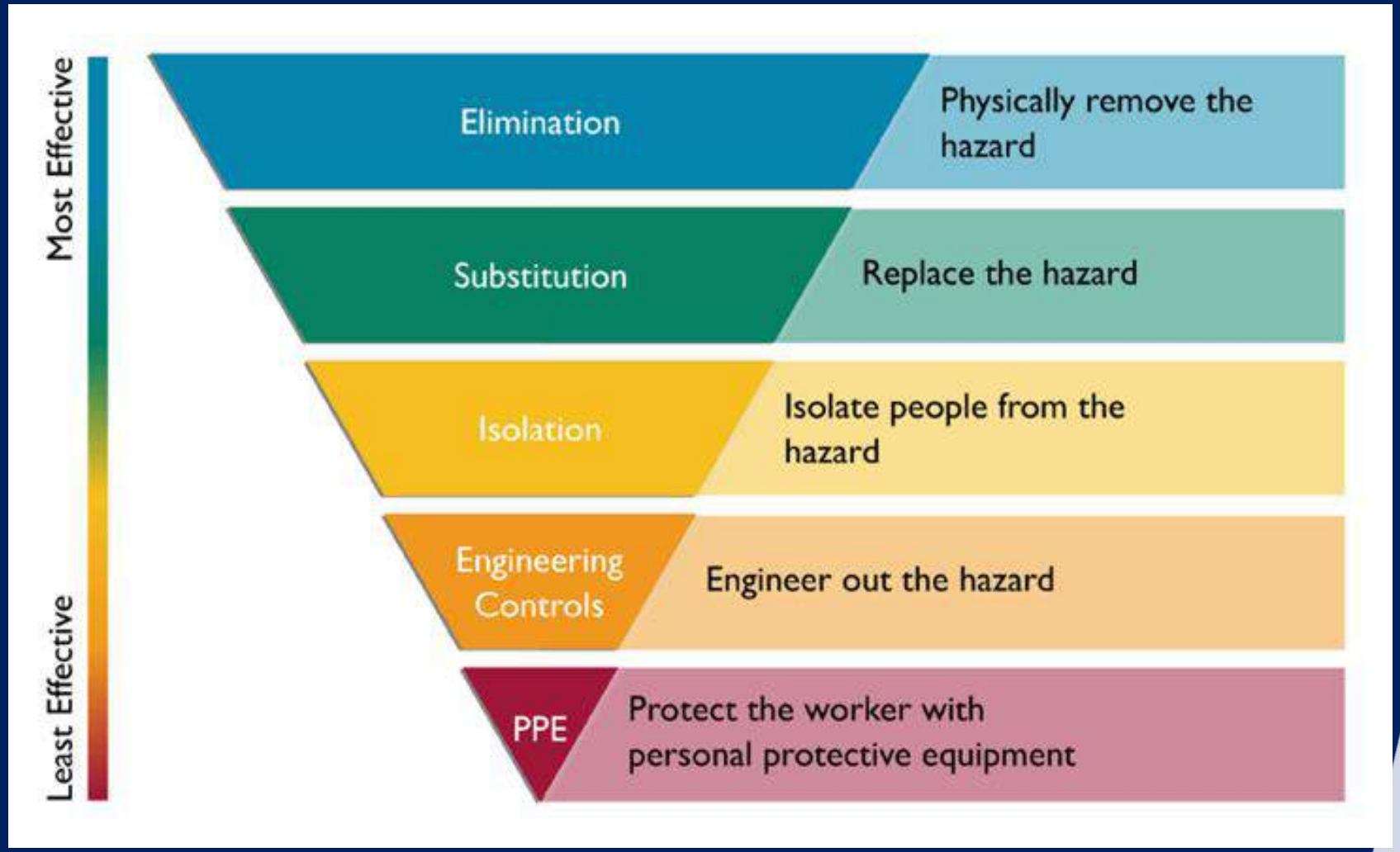
- Health and Safety at Work Act 1974 (General duty to assess risks).
- Management of Health and Safety at Work Regulations 1999 (Formalises risk assessment requirements).

The Five Steps to Risk Assessment

- Step 1: Identify hazards.
- Step 2: Decide who might be harmed and how.
- Step 3: Evaluate risks and decide on precautions.
- Step 4: Record findings and implement them.
- Step 5: Review and update as necessary.

- 🗣️ Interactive Poll:
  Which step do you think is most challenging?

Hierarchy of Control Measures



Types of Risk Assessment Methodologies

📌 1. Qualitative Risk Assessment
✔️ Simple & descriptive
✔️ Uses risk matrices

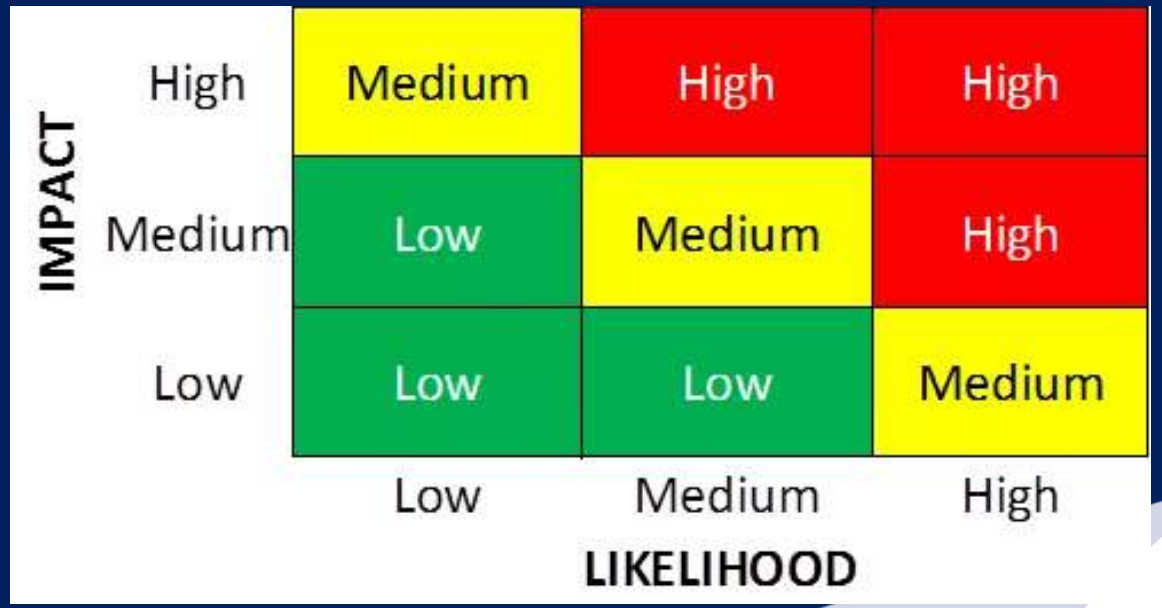
📌 2. Semi-Quantitative Risk Assessment
✔️ Uses numeric scoring
✔️ More precise ranking of risks

📌 3. Quantitative Risk Assessment (QRA)
✔️ Uses data & statistics
✔️ Often applied in high-risk industries

📌 4. Specialised Techniques
✔️ Job Safety Analysis (JSA) – Task-based
✔️ Hazard and Operability Study (HAZOP) – Process-based
✔️ Failure Modes and Effects Analysis (FMEA) – System-based

Qualitative Risk Assessment Example

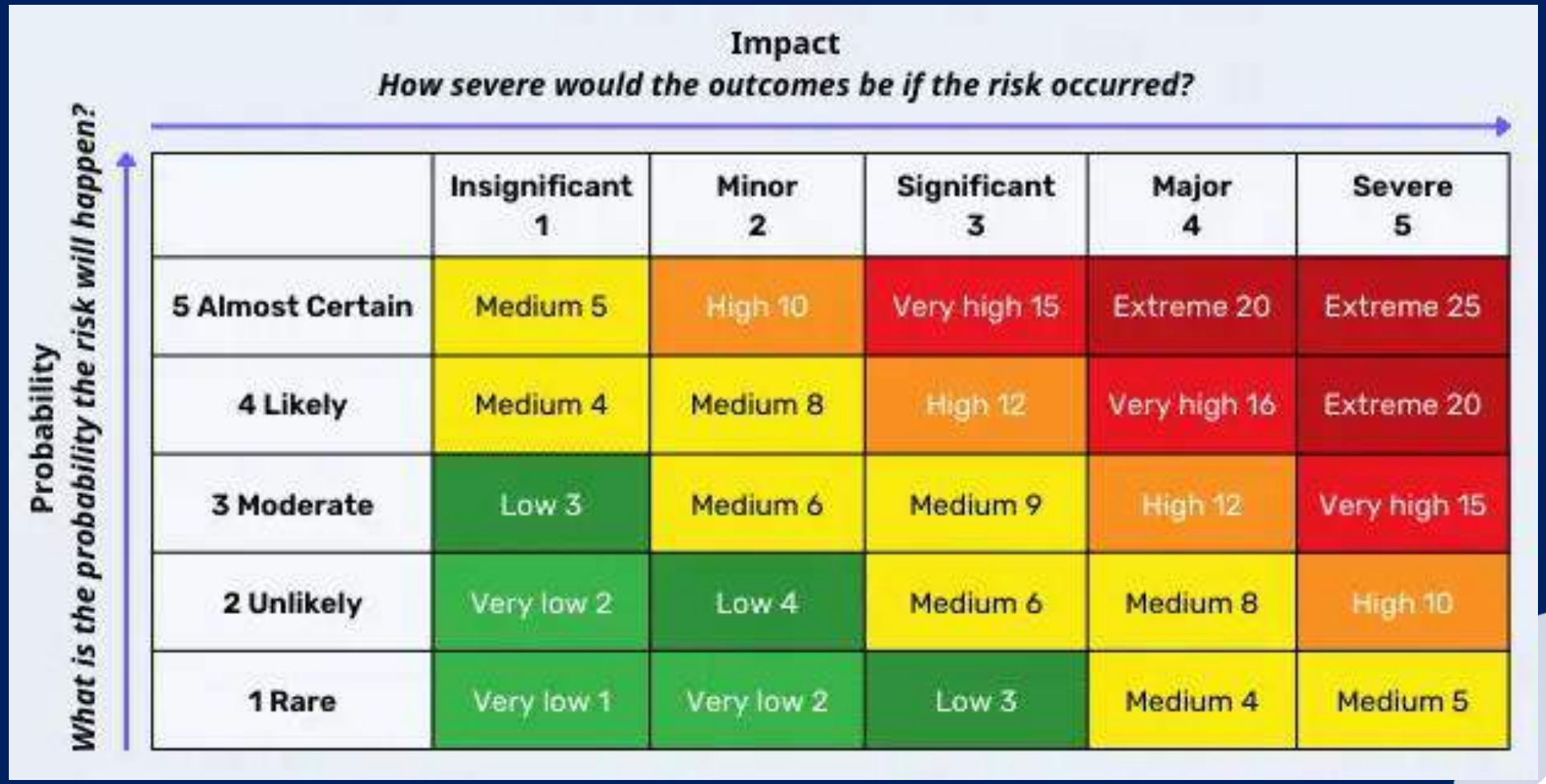
- 🟩 Low Risk: No action needed.
  🟧 Medium Risk: Control measures required.
  🟥 High Risk: Immediate action required.
- 📌 Example:
  A wet floor in a supermarket. Likelihood: High. Severity: Low/Medium. Risk Level: Medium.



Semi-Quantitative Risk Assessment

- 📊 Uses numerical scales to score risks.
  📌 Example Calculation:
- Likelihood = 4 (Likely)
- Severity = 3 (Serious injury)
- Risk Score = 4 × 3 = 12 (Medium-High Risk)

5×5 Risk Matrix Example



	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

Probability

Also called likelihood, the Probability (x-axis) pertains to the extent of how likely it is for the risk to occur. The 5 risk rating levels under this component are as follows:

- Rare – unlikely to happen and/or have minor or negligible consequences
- Unlikely – possible to happen and/or to have moderate consequences
- Moderate – likely to happen and/or to have serious consequences
- Likely – almost sure to happen and/or to have major consequences
- Almost certain – sure to happen and/or have major consequences

Impact

Also called severity or consequences, the Impact (y-axis) aims to determine the level of effects that the hazard can cause to workplace health and safety.

5×5 risk matrix can be tailored to the needs of an organisation - the following represent the general terms used to describe the 5 levels to determine the risk's impact:

- Insignificant – won't cause serious injuries or illnesses
- Minor – can cause injuries or illnesses, only to a mild extent
- Significant – can cause injuries or illnesses that may require medical attention but limited treatment
- Major – can cause irreversible injuries or illnesses that require constant medical attention
- Severe – can result in fatality
- Each risk box represents the rating of a risk that is calculated based on its particular of probability and impact. In most cases, the 5×5 risk matrix uses numeric ues represent the risk ratings.

Calculating Risks – 5x5 Matrix

Probability x Impact = Risk Level

The first step is to assign a numeric value from 1 to 5, 1 being the lowest, for each of the categories under Probability and Impact. Then, use the formula of multiplying the value of the Probability to the value of Impact to determine the Risk Level.

- 1-4: Acceptable – no further action may be needed and maintaining control measures is encouraged
- 5-9: Adequate – may be considered for further analysis
- 10-16: Tolerable – must be reviewed in a timely manner to carry out improvement strategies
- 17-25: Unacceptable – must implement cease in activities and endorse for immediate action

Quantitative Risk Assessments (QRA)

- ✔ Used for measuring workplace hazards with scientific data.
- ✔ Applies approved monitoring equipment to assess actual exposure levels.
- ✔ Ensures compliance with EU & UK OHS regulations.
- ✔ Helps determine effective control measures to prevent harm.

📌 Examples Covered in This Session:

1. Noise Exposure (Surveys & Dosimetry)
2. Airborne Contaminants (Gas, Vapour, Fumes)
3. Dust & Particulate Matter (PM Monitoring)
4. Chemical Risk Assessment (Biological & Modelling)
5. Radiation Monitoring (Ionising & Non-Ionising)
6. Heat Stress Monitoring (WBGT Index)
7. Ergonomic Assessments (Manual Handling & Posture Analysis)

Break

Quantitative RA - Monte Carlo Simulation

✔ A mathematical technique that models uncertainty in risk assessment.
✔ Uses random sampling to simulate multiple possible outcomes.
✔ Helps quantify risk levels by considering variable inputs.
✔ Applied in safety, finance, engineering, and environmental health.

https://www.youtube.com/watch?v=7TqhmX92P6U

📌 OHS Application:

- Predicting accident probabilities in high-risk industries.
- Estimating exposure to hazardous substances.
- Assessing failure rates of safety systems.

How Monte Carlo Works in Risk Assessment

📌 Step 1: Identify input variables (e.g., exposure levels, failure rates, accident probabilities).

📌 Step 2: Assign probability distributions (normal, uniform, log-normal, etc.).

📌 Step 3: Run thousands of simulations with random values.

📌 Step 4: Analyse results to find the most probable risk level.

🔹 Unlike a single risk score, Monte Carlo gives a range of possible outcomes.

Example: Solvent Exposure

Instead of: Exposure = 40 ppm (single value)

Monte Carlo:

- Exposure varies between 10–80 ppm
- Worker exposure duration varies
- Ventilation efficiency fluctuates
- After 10,000 simulations:
  - 60% probability exposure < OEL
  - 30% borderline
  - 10% exceeds OEL

Would you accept a 10% probability of exceeding OEL?

Specialised Techniques

- Job Safety Analysis (JSA) – Task-based
- Hazard and Operability Study (HAZOP) – Process-based
- Failure Modes and Effects Analysis (FMEA) – System-based

Job Safety Analysis (JSA)

- ✔️ Breaks tasks into steps.
- ✔️ Identifies hazards at each step.
- ✔️ Proposes control measures.
- 📌 Example Task: Steel Fabrication Workshop

Step 1: Break Task into Steps

1. Preparation – Gathering materials, setting up tools and workspace.
2. Cutting steel beams – Using a cutting torch or angle grinder.
3. Welding joints – Fusing steel components together.
4. Inspection & Cleanup – Checking weld quality, removing debris.

Then continue with the rest of the steps: ID Hazards, Evaluate etc...

HAZID (Hazard Identification Study)

Objective

- Identify all credible hazards at an early project or process design stage.
- Focus on *what can go wrong?*

When Used

- Concept design phase
- Before detailed engineering
- Large projects (construction, pharma expansion, oil & gas)

Method

- Brainstorming workshop
- Multidisciplinary team
- Use of prompt lists (energy sources, chemicals, confined spaces, human factors)

Typical HAZID example

Location: Platform ABC

Prepare MAH Sheets for Export to BowTieXP

Code	Hazard	Sources	Threats (separate with ;)	Top Event	Consequences (separate with ;)	Controls (separate with ;)	Risk														Comments	
							People			Assets			Environment			Reputation						
							Frequency	Severity		Frequency	Severity		Frequency	Severity		Frequency	Severity					
H-01	**Hydrocarbons**																					
H-01.01	Oil under pressure	Well testing	Overpressure; Dropped Object; Human Error	Loss of Containment	Unignited Release; Fire; Injury/Fatality; Alternative consequence	Pressure relief valves; Continuous monitoring of well test operations; Restrictions on lifting operations; Permit to work and Well Test Procedures	>1 / year in location	Multiple fatalities	E3	Never heard of	No damage	A1	> 0 in industry	Localised effect	B3	Never heard of	Slight impact	A2				Major Accident Hazard
H-01.02	Driving a vehicle	Road transport	Loss of attention; Slippery road; Low visibility	Loss of Containment	Crash; Pedestrian hit; Collision with vehicle	ABS; Seatbelt; Defensive driving; breath alcohol ignition interlock device	> 0 in industry	Slight injury	B2	Never heard of	No damage	A1	>1 / year in our company	No effect	D1	> 0 in our company	Considerable impact	C3				
H-01.03	Aircraft taxiing	Air transport	Miscommunication; Poor visibility; Wildlife in path	Runway Incursion	Collision; injuries/fatalities persons in vicinity; Impact to passengers/flight crew	Enhanced vision system; Appropriate charts; Fencing/long grass; Periodical medical check	> 0 in our company	Multiple fatalities	C3	> 0 in our company	Major damage	C4	> 0 in our company	Localised effect	C3	> 0 in our company	International impact	C3				Major Accident Hazard

HAZOP (Hazard and Operability Study)

📌 Objective: Identify process hazards and operability issues in complex systems like chemical plants, manufacturing, and oil & gas operations.

📌 How HAZOP Works:

✔️ Systematically examines each process step for potential deviations.

✔️ Uses guidewords (e.g., "More," "Less," "No," "As well as") to analyse possible failures.

✔️ Involves a multidisciplinary team (engineers, OHS professionals, operators).

📌 HAZOP Process Steps:

1️⃣ Define the system/process – e.g., a steam boiler system in a factory.

2️⃣ Break it into sections – (e.g., water feed, heating, steam output).

3️⃣ Apply guidewords to each section – e.g., "No Flow" → Water pump failure.

4️⃣ Identify causes & consequences – No water flow → Boiler overheating → Explosion risk.

5️⃣ Recommend controls – Redundant pumps, automatic shu

HAZOP (Hazard and Operability Study)

📌 Example – HAZOP on a Chemical Mixing Tank:

Guideword	Deviation	Possible Cause	Consequence	Control Measure
More	Overpressure	Blocked outlet valve	Tank rupture	Pressure relief valve
Less	Low Flow	Pump failure	Incomplete mixing	Pump redundancy
No	No Flow	Valve left closed	Process stop	Operator checklist

📌 Applications:

✔ Used in high-risk industries (oil refineries, pharmaceutical manufacturing).

✔ Best for processes where failures can have catastrophic consequences.

Typical HAZOP RA table

Node: 1. *Tank T-001 and nitrogen purge*

Deviation	Session	Causes	Consequences	CAT	Risk rating before safeguarding							Safeguards					Critical safeguards			Risk rating after safeguarding			HAZOP Recommendations	Responsibility for recommendation	Risk rating after completion of recommendations		
					Original risk			Existing/Modifies/Design	Corrected risk			Instrumental			Other safeguards (e.g. Alarm + operator action/Mechanical/Mitigation)												
					S	F	RR		S	F	RR	Sensor TAG-nr	Final element TAG-nr	Final element Action	Effective Action		Description	Type	RRF	S	F	RR			S	F	RR
1. Flow High	1. 9-11-2018	1. V-003 is open during solvent filtration. Human error.	Continuous evaporation of solvent in T-001 (towards Vapor Return). T-001 level decreases. P-001 / P-002 runs dry. Potential pump damage.	A	S1	F5	Low Alarm					2. LS-002	1. P-001	Stop pump	1. Yes		7. LS-002 stops pump P-001 & P-002 (and P-100 & P-200)	Instrumental	10x	S1	F4	Low					
													2. P-002	Stop pump													
													3. P-100	Stop pump													
													4. P-200	Stop pump													
2. Flow Low	1. 9-11-2018	1. No credible causes/consequences identified.																									
3. Flow No	1. 9-11-2018	1. No credible causes/consequences identified.																									
4. Flow Reverse	1. 9-11-2018	1. No credible causes/consequences identified.																									
5. Pressure High	1. 9-11-2018	1. PC-001 fails open or wrong setpoint. Nitrogen purge is only used during solvent operation.	Pressure in system rises to max 16 barg. P operation is >> P design T-001, T-001 will fail mechanically. Assumption: T-001 fails at its top lid. Lid will lift. People may come into contact with harmful (corrosive) vapor/liquid (spray). Expected to be severity S3 (medical treatment).	P	S3	F5	High Alarm	1. People present: 100% during nitrogen purging. 2. Probability of being hit by liquids and obtain S3 severity: 10%	S3	F4	High Alarm						1. V-xxx pressure control valve can relief max 25 m3/h.	Mechanical	10x	S3	F3	Low Alarm	1. Install pressure relief valve on vessel (outlet to safe location) to protect against -overfilling scenario (sizing according to max feed flow) -Nitrogen supply failure (fail open)		S3	F1	Low

HAZID vs HAZOP

HAZID	HAZOP
Broad	Detailed
Early stage	Detailed design stage
What hazards exist?	What deviations can occur?
Faster	Time intensive

💬 **Why would performing HAZOP without HAZID first be weak?**

FMEA (Failure Modes and Effects Analysis)

📌 Objective: Systematically identify potential failure modes in a system, product, or process and prioritise them based on risk.

📌 How FMEA Works:

✔ Identifies all possible ways a system/process can fail.

✔ Assesses the severity, likelihood, and detectability of each failure.

✔ Calculates a Risk Priority Number (RPN) to prioritise actions.

FMEA (Failure Modes and Effects Analysis)

📌 FMEA Process Steps:
1️⃣ List all process steps/equipment components – e.g., hydraulic press operation.
2️⃣ Identify failure modes – e.g., "Hydraulic pressure loss".
3️⃣ Determine effects of failure – e.g., "Production stoppage, safety hazard".
4️⃣ Assign scores for:
- ✔️ Severity (S) (1–10) → Impact of failure.
- ✔️ Occurrence (O) (1–10) → Likelihood of failure.
- ✔️ Detection (D) (1–10) → Likelihood of detecting failure before impact.

5️⃣ Calculate Risk Priority Number (RPN):
RPN = S × O × D
6️⃣ Prioritise actions for high-RPN failures.

RPN Made Simple in FMEA

In Failure Modes & Effects Analysis (FMEA), the Risk Priority Number (RPN) helps teams prioritize risks and take the right actions.

🔢👉 Formula:
RPN = Severity (S) × Occurrence (O) × Detection (D)

✅ How to Interpret RPN:

1 – 50 → Low Risk (Monitor, minimal action needed)

51 – 100 → Moderate Risk (Consider improvements)

101 – 200 → High Risk (Action required to reduce risk)

201 – 1000 → Very High / Critical (Immediate corrective actions needed)

RPN Made Simple in FMEA

Every failure isn't equal. In FMEA, the Risk Priority Number (RPN) helps us decide which issues need urgent action.

RPN = Severity × Occurrence × Detection

But what do the numbers actually mean? Here's a simple guide:

RPN Correlation Table	Action
1 – 50	Low Risk
51 – 100	Moderate Risk
101 – 200	High Risk
201 – 1000	Very High / Critical

Golden Rule: Never chase the number alone. Even a low RPN with high severity (like a safety risk) deserves urgent action.

FMEA isn't just about calculation – it's about focusing efforts where they matter most: safety, quality, and customer trust.

FMEA (Failure Modes and Effects Analysis)

Classification Table example:

RPN Range	Risk Level	Action Required
RPN > 200	🔴 High Risk	Immediate corrective action required.
RPN 80–200	🟠 Moderate Risk	Risk reduction measures recommended.
RPN < 80	🟢 Low Risk	Monitor & maintain controls.

FMEA (Failure Modes and Effects Analysis)

📌 Example – FMEA on a Hydraulic Press Machine:

Failure Mode	Effect	Severity (S)	Occurrence (O)	Detection (D)	RPN (S × O × D)	Control Measures
Hydraulic failure	Loss of pressure → Machine stops	8	6	5	240	Preventive maintenance
Sensor failure	No emergency stop activation	10	3	4	120	Regular sensor testing

📌 Applications:
✔ Used in manufacturing, aerospace, healthcare, and automotive industries.
✔ Helps prioritise risk mitigation efforts for high-failure-risk components.

Comparison – HAZID vs. HAZOP vs. FMEA

Feature	HAZID	HAZOP	FMEA
Scope	Broad/High-level	Detailed/Systematic	Component/Detailed
Stage	Conceptual/Early	Detailed Design	Design/Operational
Approach	Brainstorming	Deviations (Guide words)	Failure modes
Main Goal	Hazard Identification	Operability & Safety	Component Reliability
Best For	Identifying site hazards	Process plant safety	Equipment failure

Reviewing & Updating Risk Assessments

🔁 Risk assessments must be regularly reviewed to remain effective.

✅ When to review?

- After an incident or near miss.
- When work conditions change.
- If new hazards emerge.

Breakout Activity

- Scenario: A factory with moving machinery and chemical storage.
- Task:
  - Choose an appropriate risk assessment methodology.
  - Justify your choice.
  - Suggest basic controls.

⏳ Time: 10 minutes (Breakout Rooms)

Summary & Key Takeaways

- ✔ Risk assessment is critical for workplace safety.
- ✔ EU & UK laws require systematic risk assessments.
- ✔ Different methodologies suit different situations.
- ✔ Risk assessments must be regularly reviewed.

21 ACADEMY

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