Bridging the gaps for Industrial Risk Assessment and Emergency Response Planning

By: A. Perseval, Principal Process & Safety Consultant, Shamrock HSE Consultancy and M. Baldeo, Project Management Consultant, Arkulus Solutions.

Abstract

Process industry evolution and experience has led us to develop formulated processes for 'Risk Assessments' and to ensure the appropriate safeguards, mitigations and elements of Contingency Planning/Emergency Response Plans are in place to protect our workplace activities on any industrial site. This paper addresses why some gaps in the risk assessment processes still occur and identifies areas for improvement in implementing Emergency Response Plans (ERPs) during a Major Accident Hazard (MAH) event using a hypothetical incident as a case study.

In this case study, a hypothetical Process Safety Incident occurs on a subsea pipeline which results in multiple fatalities. The incident will be used to illustrate how applied risk assessment methodology gaps and human factors may have led or contributed to an incident and resulting consequences. It recommends solutions as to how our approach can be improved through alternative methodologies, best practices, and the use of technological integration in the Process Safety Management arena.

Disclaimer: The objective of this paper is to help improve the way we approach risk assessments in the industry so that we can be better prepared to respond if an incident occurs. Nothing in this paper constitutes legal advice, blame or judgement in the risk assessment process.

Key words: Risk Assessment, Major Accident Hazard, Process Safety Engineering, Process Safety Management.

Introduction (Identifying Issues)

International Standards such as IEC 61882 HAZOP Studies[1], ISO 31000:2018 Risk Management[2], IEC 31010:2019 - Risk Management - Risk assessment techniques[3] have been developed as pillars in our approach to risk management across industry. Risk Assessments processes and procedures reference these applicable standards to provide a structured methodology for many organisations to effectively manage risk exposure during site operations. These risk assessment systems ensure the appropriate safeguards, mitigations and elements of contingency planning are in place to protect our workplace activities on any industrial site, generally setting risk tolerances to as low as reasonably practicable - ALARP Principle illustrated below in Figure 1:

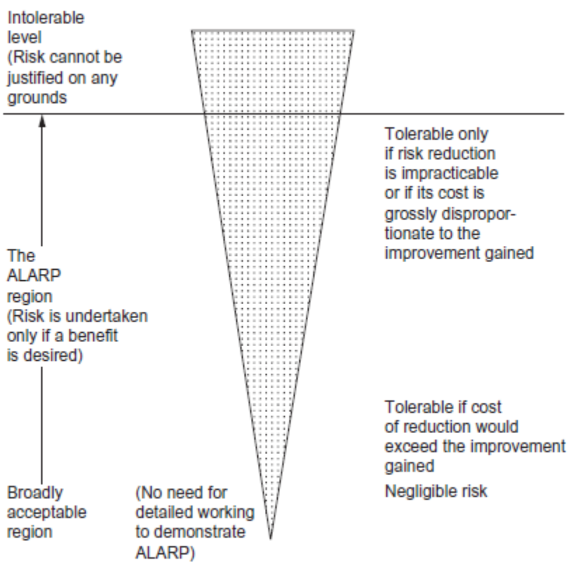

Figure 1 - The ALARP Principle (HSE, 1988c). Source: Courtesy of HM Stationery Office.[12]

Risk Assessments are essential tools in decision making processes and play an integral role in the success of health and safety management systems. However, shortfalls in risk assessment processes or even the routine approach taken to conduct risk assessments can increase the severity of hazardous events or omit vulnerable areas in a planned activity that may contribute to an unplanned hazardous event. This paper addresses why shortcomings in the risk assessment process still occur, identifies human factors and risk management system gaps using a hypothetical case study example and discusses how they can affect emergency response during a Major Accident Hazard (MAH).

Conducting Risk Assessments

Risk Assessment is the process of identifying applicable hazards and estimating the likelihood of occurrence of undesirable events and the severity of the harm or damage caused, along with a value judgement relating to the significance of the results. When choosing a risk assessment method, factors such as the type of industrial process, correct identification of hazard types, levels of associated risk and the stage of the project life cycle, project activity, previous lessons learnt, should all be considered. Risk assessments can be qualitative, semi-quantitative or quantitative processes. Qualitative & semi-quantitative Risk Assessments approaches include What-if Analysis, Hazard Identification (HAZID) study, Hazard and Operability (HAZOP) study, Failure Mode and Effect Analysis (FMEA), Layer of Protection Analysis (LOPA) and are dependent on level of judgement, experience and knowledge whilst fully quantitative approaches include Quantitative Risk Assessment (QRA), Probability Risk Analysis (PRA) and Quantitative Scenario Analysis (QSA) are derived from the quantification of potential hazard consequence and relevant risks[6].

Though the purpose of conducting each type of risk assessment is ultimately the same, that is identifying and reducing the risks of potential hazard events to as low as reasonably practicable, a common shortfall when conducting risk assessments is the selection of the appropriate risk assessment type or approach to be used. Essentially, the degree of detail in the risk assessment should be commensurate to the level of the intrinsic hazard. That is, as the severity of consequence of the hazards under consideration and the complexity of the systems being assessed increases, the robustness of the risk assessment should also increase[7]. Selection of the most appropriate risk assessment approach based on the degree of consequence of a particular hazardous scenario prevents against the use of generic risk assessments when more site or work specific/task risk assessments may be required. For example, a particular cause in a HAZOP where the consequence of the hazardous event is high, should trigger a Layer of Protection Analysis (LOPA) for that specific event. This identifies if additional layers of protection are required and if they are provided, using safety instrumented functions (SIFs), what that reliability of the SIFs needs to be.

Another common pitfall when conducting risk assessments is the failure to involve key team members in the assessment process or, if the right representation isn't there maybe there is a lack of technical expertise, such as a Subject Matter Experts (SMEs) due to competing work priorities. Appropriate team selection for the risk assessment process is crucial in adequately assessing the potential outcomes of hazardous operations. The expertise of team members should be relevant to the risk assessment problem statement or enhancement requirement and study context. Questions like, "What type of expertise and subsequent degree of competency would best contribute to the risk assessment study?", should be considered when determining the best suited members for the team. Organizations may have to outsource members to participate in the risk assessment studies, for example in cases of work carried out by external contractors. The involvement of parties actually involved in the potentially hazardous events being analysed is essential to the quality of the risk assessment study as the assessment scope may require the expertise of individuals who are more familiar with the nature of work to be carried out.

Team members' attitude toward risk management can also determine the success or failure of the risk assessment process. This shortfall is related to the influence of human factors on accident causation. Usually, the direct effect of human factors as contributors to major accidents would be considered such as the increased likelihood of occurrence of accidents when organizations lack or do not enforce safety rules and regulations thereby reducing the level of safety awareness of employees[8]. However, organizational safety awareness may not necessarily translate to individual competence at all times. If employees feel that the risk assessment process is becoming repetitive or monotonous, employee complacency in tasks may arise, potentially decreasing awareness of or desensitizing persons to glaringly obvious hazardous scenarios as they emerge [9].

For site operations it may be desirable to quantify and rank the risks arising from human failures. Several methods exist for quantifying the contribution made by human action or inaction to the overall risk. Human Reliability Assessment (HRA) include the process of task analysis which helps with the identification of all points in a sequence of operations at which incorrect human action, or the failure to act, may lead to adverse consequences[5]. Procedural HAZOPs may well be applicable in high risk, manual/semi manual site operations and should be implemented to capture the human factor elements and provide a more in-depth analysis.

Other common pitfalls of risk assessment include[7]:

- Carrying out a risk assessment to attempt to justify a decision that has already been made;
- Using a generic assessment when a site-specific assessment is needed;
- Carrying out a detailed quantified risk assessment without first considering whether any relevant good practice was applicable, or when relevant good practice exists;
- Carrying out a risk assessment using inappropriate good practice;
- Carryout risk assessment with poor facilitation and control (e.g. results in conflict between parties, missed hazards or dominant personalities taking control)

- Making decisions on the basis of individual risk estimates when societal risk is the appropriate measure;
- Only considering the risk from one activity;
- Dividing the time spent on the hazardous activity between several individuals - the 'salami slicing' approach to risk estimation;
- Not involving a team of people in the assessment or not including employees or executing contractors with practical knowledge of the process/activity being assessed;
- Ineffective use of consultants;
- Failure to identify all hazards associated with a particular activity;
- Failure to fully consider all possible outcomes;
- Inappropriate use of data;
- Inappropriate definition of a representative sample of events;
- Inappropriate use of risk criteria;
- No consideration of ALARP or further measures that could be taken;
- Inappropriate use of cost benefit analysis;
- Using 'Reverse ALARP' arguments (i.e., using cost benefit analysis to attempt to argue that it is acceptable to reduce existing safety standards);
- Not doing anything with the results of the assessment;
- Not linking hazards with risk controls.

The importance of Emergency Response Planning.

An Emergency Response Plan (ERP) is a detailed program of action to control and/or minimize the effects of an emergency requiring prompt corrective measures beyond normal procedures to protect human life, minimize injury, to optimize loss control, and to reduce the exposure of physical assets and the environment from an accident. ERPs are purposed to develop a state of readiness such that the response to any emergency is prompt, orderly and effective. The Emergency Response Planning procedure should have the objectives of understanding the type and extent of consequence of potential emergencies, establishing a high level of emergency preparedness, ensuring well-organized and timely decision-making response processes and providing incident management with clear goals and actions by the appropriate lines of authority.

Emergencies will fall under the scope of 'Non-routine' activities in the Risk Assessment workflow (Figure 2). Therefore, the practical use of an ERP would take place thereafter in the mitigative/prevent response section of the Risk Assessment workflow. A common gap with this approach is that in referring to the ERP as the answer to a Mitigation, stakeholders of the Risk Assessment may take the ERP for granted as a document that exists as a '*silver bullet'* solution, but not necessarily effective in responding to a site-specific hazardous event.

It is important that an experienced Health, Safety and Environment (HSE) member, who is familiar with the ERP, confirm that effective credit can be taken from the plans identified in the ERP. This test may prompt an action to create a site or project specific ERP.

Effective Emergency Management or Crisis Management implies that plans are put in place for all identified emergency scenarios prior to site operations. Subsequently, based on the outcome of the risk assessment, emergency plans can be further developed, financial/human resource and knowledge gaps can then be addressed prior to the occurrence of the emergency scenario.

The Risk Assessment Workflow

A dynamic approach should be taken to the Risk Assessment process by considering four (4) phases of risk assessment during the project activities: Pre-works, Site works and Mitigative/Preventive Response and Post-works. Figure 2 illustrates this below:

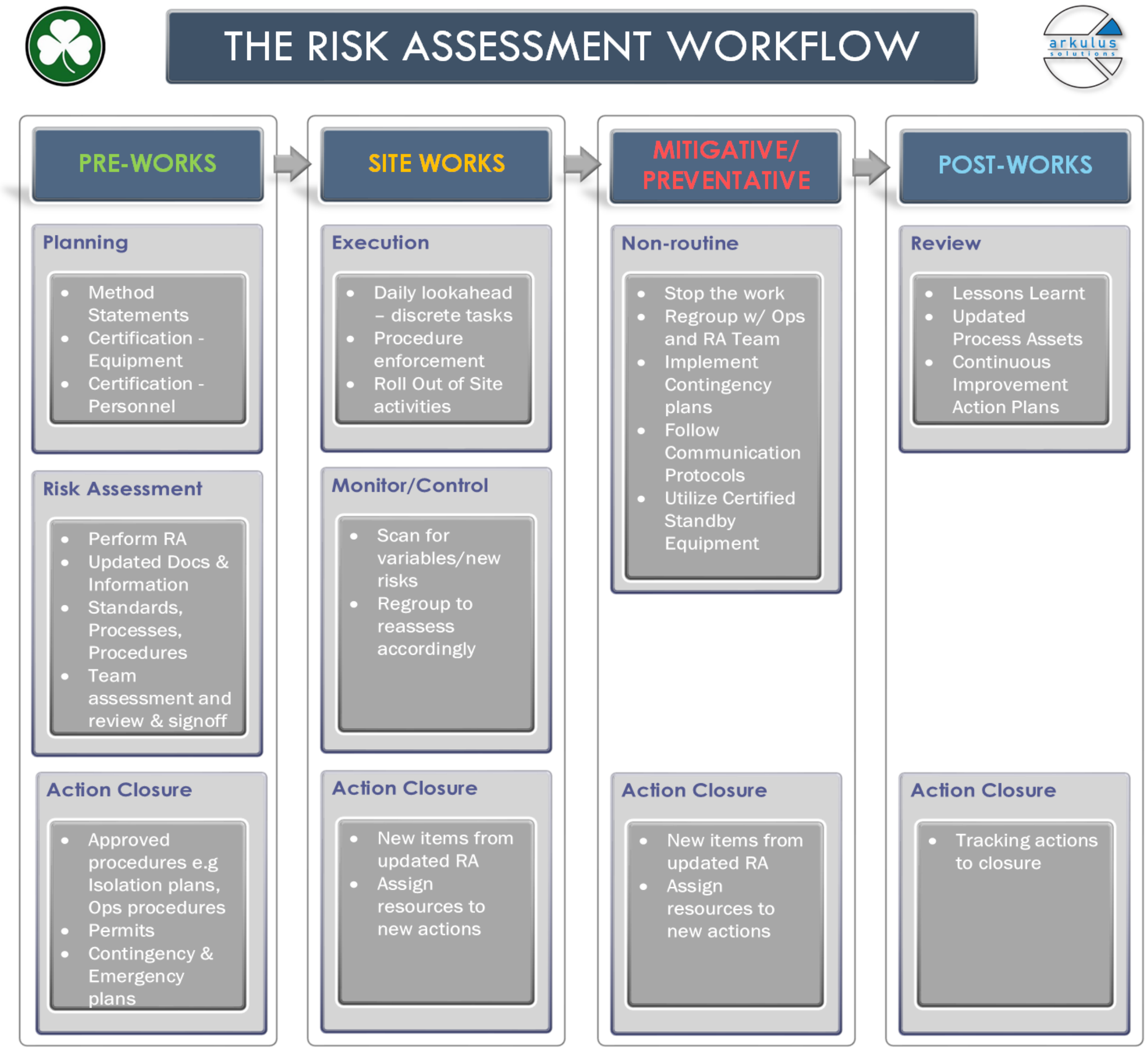

Figure 2 – The Risk Assessment Workflow.

1) *Pre-works Phase:* Also known as the Planning Phase, is where all relevant information and documentation necessary to execute the site operations is identified and prepared in advance. The risk assessment is conducted in a calm frame of mind as the team identifies and assesses the hazards using the appropriate formalized risk assessment methodology. At this stage, the selection of the team both from technical experience and technical applicability would be performed. Technical Experience refers to the individuals' competence and years' experience in the industry in relation to the work site activity. Technical Applicability refers to the composition of the team ensuring the right cross section of team members are selected for the type of activity. For example, considering a hot work type activity on a pipeline, the core team should have adequate representation from Mechanical, Process, Construction, HSE, Pipeline Subject Matter Expert, Operations Team, and a Project Manager, but unlikely to include Civil or Electrical representatives. If, however, as the Risk Assessment progresses, discipline risk areas are discovered requiring assessment, the respective discipline technical representatives must be added to the core team or called upon to make an intervention.

Contractor experience is also key as the party experienced in undertaking the work activity can provide great insight and shed light on work approaches. An experienced executing contractor will most likely possess the practical knowledge for a technical work scope. It is important to re-emphasize that during this phase, the mood of the team is most calm, and that the team's ability to be most strategic lies here in identifying and planning for all resources, (personnel and equipment), and establish a sense of gravitas in developing contingency and/or project specific Emergency Response Plans as necessary.

Cascade risks are a type of risk characterized by a 'domino effect' of one risk impacting on another; this risk type should be identified early in the planning stage where possible. The order of the risks impacting each other may happen in series or parallel with a compounding effect that has the potential to lead to a hazardous consequence not initially considered or even a Major Accident Hazard event. Most organizations only consider individual risks and the impact of those on the organization and may miss out the abridged effect of multiple risks impacting on different areas of site or operational activities. As early as possible, the Team should develop the habit of continuously scanning for and identifying Cascade risks.

2) *Site Works Phase*: After the electronic or paper-based Risk Assessment is approved to commence work, the process parameters and environment must be continuously assessed. Regular audits should be conducted by the Project team with active assessment by key team members such as the Construction Supervisor, HSE tag and Project Manager, to assess and identify new variables such as new information or changes to process conditions. Introductions to new hazards may also arise such as Simultaneous Operations (SIMOP) activities carrying cascade risks that can impact the method of execution of the project activity. Depending on the changes in conditions, safety stand-downs or revisits to the previous Risk Assessments and Lessons Learnt may be warranted. Monitoring of parameters is key at this stage, as it provides indicators of variance, a sign that what was previously assessed, may now be obsolete. The use of technology can be of great benefit here as it can effortlessly and accurately track data, trigger alarms, identify values outside of acceptable limits and provide trends for future activities of similar nature.

3) *Mitigative/Preventative Response Phase:* This occurs if a potential incident is taking place on the work site. The mood will now be a lot different to the previous phases and this is where all parties must remain calm in order to roll out contingencies, as individuals must now make quick decisions based on experience and the information available at hand. Organizations must have a robust Business Continuity Plan (BCP) and an Emergency Response Plan (ERP) ready to follow. These plans must be developed and tested/drilled from the *Planning Phase* to ensure they will add great value and play a critical role in re-stabilizing the work activity in play and the business as a functioning entity.

The focus during this phase should be following procedures outlined by a tested plan, rather than trying to develop one, similar to the Ability to Influence a Project vs Cost graph (Figure 3), and the Ability to Remain Calm vs Project Consequence curves (Figure 4) repel each other as time moves along. See graphs below:

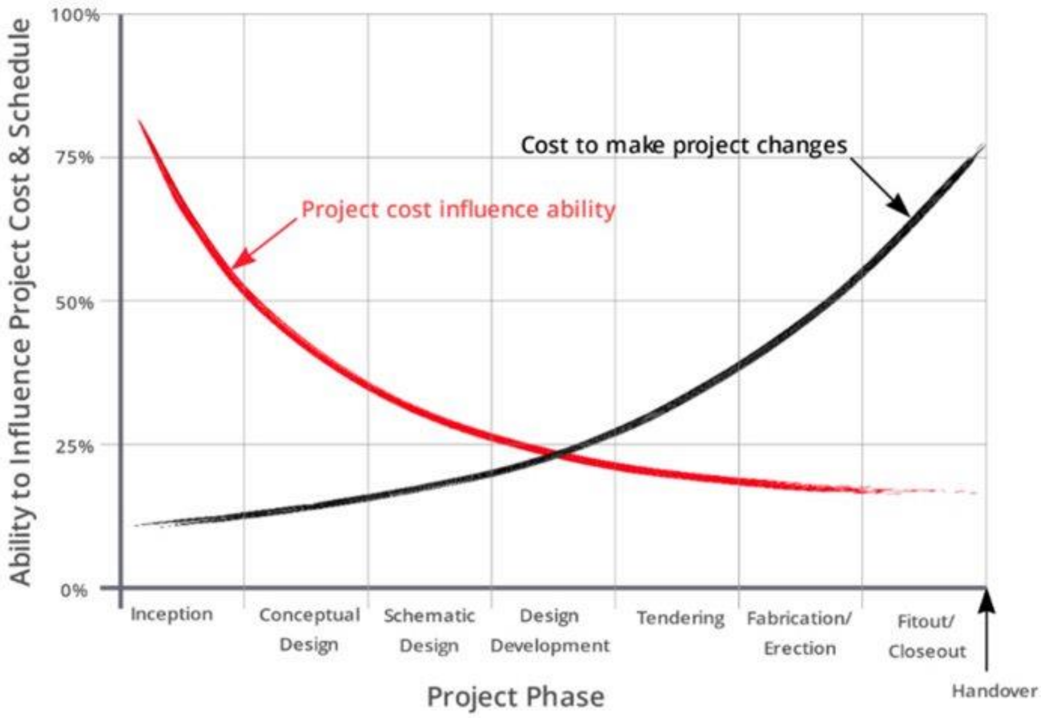

Figure 3 – Ability to Influence Project vs Project Cost

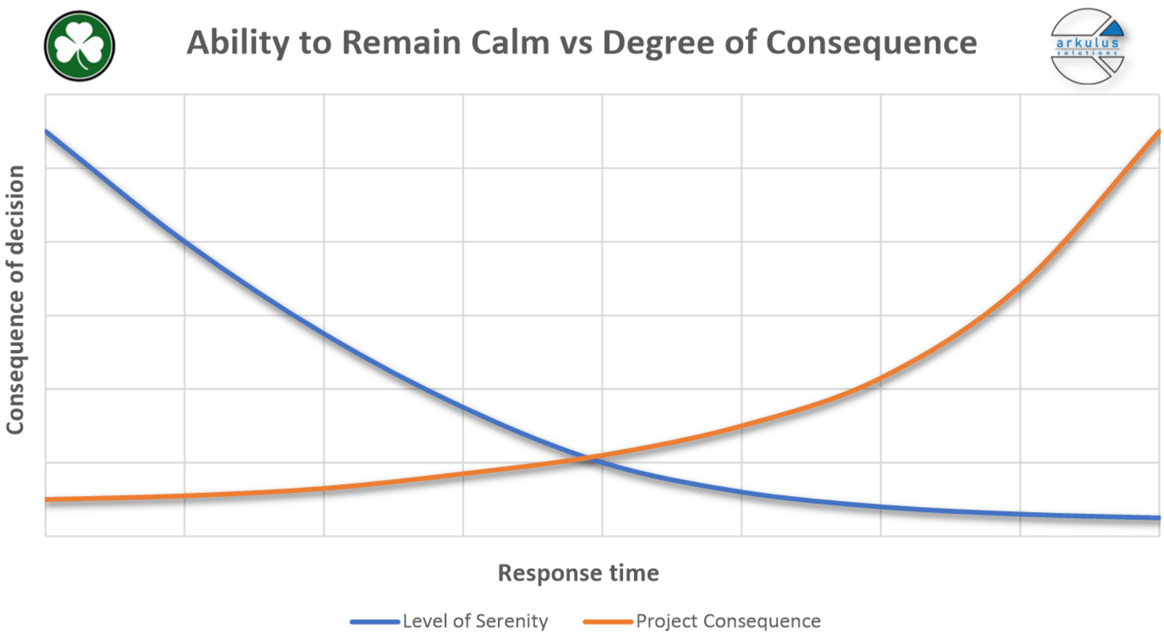

Figure 4 - Ability to Remain Calm vs Degree of Consequence

All items identified in contingency planning during the Pre-works phase, must be available on site, prior to the start of the work activity. This includes approved procedures, clear ERP identified for use, key personnel and equipment ready, certified and available for use. If it is not practical to stage all the solutions, adequate emergency plans for each scenario to stabilize the situation can be prepared and time taken to mobilize said resources must be factored in. For example, most site work usually carries a degree risk of injury depending on the work activity, if it is not practical to have an ambulance on site, instead having a trained HSE officer who can provide necessary support to stabilize the Injured Person (IP) until the professional medical response arrives is a viable alternative.

At this stage, if the incident revolves around HSE consequence, every hour, minute, second counts, so upfront planning is critical to successful mitigation. The main focus of this phase is trained reacting, to be executed as calmly and quickly as possible, so as not to contribute to worsening the situation.

It's worth noting that for many project activities, we may never experience this phase. This does not necessarily mean that excellent mitigation measures were in place, but instead, simply means a hazard event did not occur leading to a potential consequence, whether it be Safety, Environmental or Production impacting.

4) *Post-Works Phase*: This is a last phase of the workflow where the site operations are completed, and any incidents have been dealt with in the most effective way possible using best practice from the planning phase. The mood is reflective, and the mindset is how could the team improve on what was done, what lessons can be captured and taken forward for continuous improvement to reduce risks and provide future reference. This includes updates of all relevant process assets of the organization. There is valuable information in this stage and documenting the learnings while it is still fresh in the Team's minds is key to the success of future projects.

Application of Risk Assessment Workflow methodology - Understanding Issues

Case Study: Process Safety Incident at Offshore Facility Subsea Pipeline

Background

On the day of the incident, a private Contractor, was conducting a maintenance exercise involving replacement of isolated subsea spool on a hydrocarbon pipeline when an incident occurred at an offshore unmanned facility. The incident resulted in the loss of sight of three offshore workers (divers) in the vicinity of the work area. Immediate rescue attempts for the missing personnel were initiated, with one worker being rescued, but further rescue attempts were subsequently halted by what was deemed by the Operator company as intolerable risk. This created great controversy amongst several stakeholders involved in the incident, including the Contractor team members, who were restricted from gaining access to the location of the event. During this misalignment, valuable time was lost in assessing the hazard scenario and locating the missing workers, as the fear grew that missing persons could possibly drown due to possible injuries from the incident. The level of preparedness, Emergency Response Planning and adequate mitigants did not appear to be implemented quickly enough in a situation where time was of the essence.

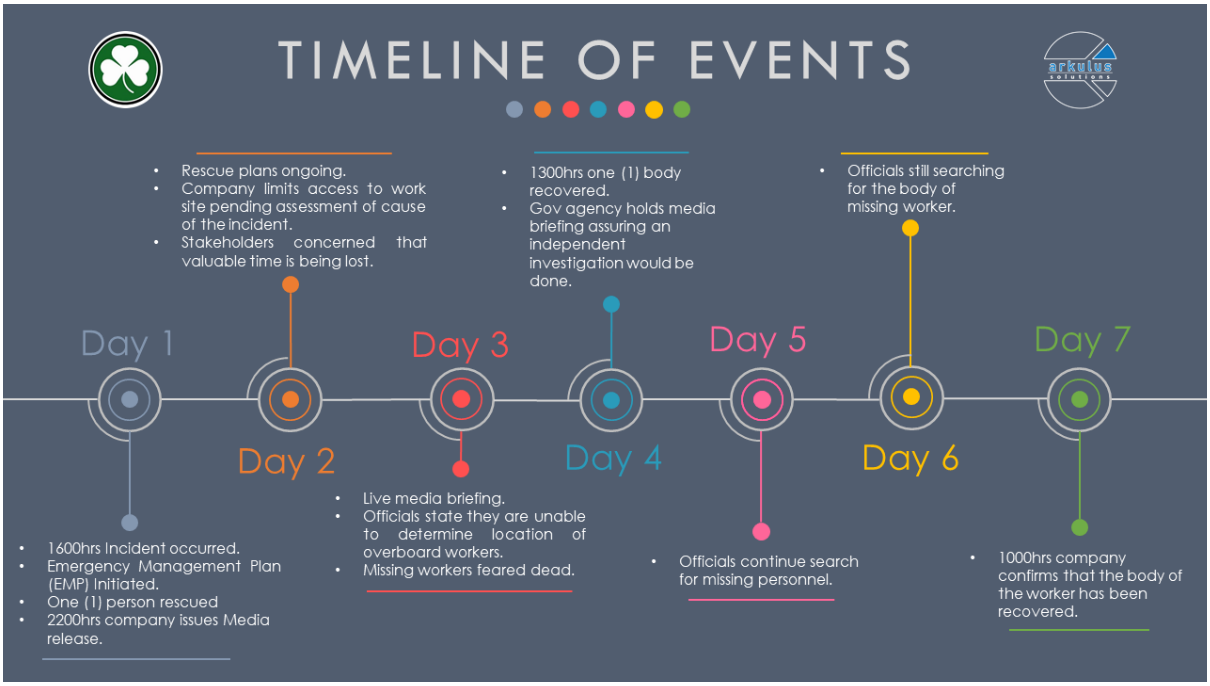

Figure 5: Timeline of Events.

The severity of the outcome of the incident raises a few key questions:

- Was this worksite adequately risk assessed with the participation of the best-suited technical team?
- Were all actions tracked to closure?
- Was there a well-defined and communicated Emergency Response Plan for all different scenarios?
- Were key stakeholders involved in assessing the worksite activity familiarized with the Emergency Response Plan?
- Was there a communication plan in place for all activities related to the pipeline for the duration of the job?

By applying the Risk Assessment Workflow methodology, the incident can be analysed to highlight possible factors that may have contributed to the gaps in the risk assessment process and breakdown in the Emergency Response Plan.

Pre Works

Typically, planning would consist of identification of the risk assessment scope, gathering of required human and tangible resources including the Risk Assessment team and necessary supporting documentation (operating procedures, standards, engineering drawings, SIMOPs, permits, isolations, protocols, agreements, work plans etc.) to determine the type of risk assessment to be used, identification of the stakeholders involved in the work activity and knowledge of the relevant laws, regulations, codes and standards applicable to the nature of work. Familiarity with the organization's policies, procedures, process safety culture and all site operations considered as inputs to the risk assessment.

Other additional high-level points for this phase are noted below:

- Since the work activity required subsea operations, **the risk assessment scope** should include the assessment of risks associated with this type of operations: hazard identification, risk analysis, and risk evaluation of associated hazards of subsea operations as well as emergency scenarios (first step in emergency planning). An examination of the Management of Change (MOC) procedures may add further insight as well. For example, if the job was considered a 'like for like replacement', it may have been considered low risk, even though subsea diving activities are inherently high risk and thus a lower level of oversight and the risk assessment approach may have been incorrectly applied.
- **A procedural risk assessment** for each stage of the work activity should be conducted with an experienced Process Hazard Analysis (PHA) Team Leader along with relevant operations team members, and Subject Matter Experts (SMEs). This ensures involvement of all personnel familiar with the work area, as well as personnel who are not, so that both the experienced/inexperienced personnel can offer new perspectives, challenge safety, offer positive contributions and stay informed of site Operations.

- The **Control of Work** process, which includes isolation of pipeline (Lock-Out/Tag-out) and physical isolations, needed to be in place to ensure adequate barriers are in place. This includes physical walkdowns of all inlet/outlet points that may change pipeline conditions and signed documentation/drawings supporting this.
- **Accuracy of documentation** is important as there may have been gaps, errors or omissions which required further verification to ensure 'As-Built' information is correctly shown.
- **Emergency Response Plans** should have been reviewed and revised accordingly and any gaps closed prior to the execution of the work. This includes all scenarios, communication protocols, Responsibility Assignment Matrix, Emergency isolation/Plugging of Pipeline procedures in case of leaks or isolation breach, SIMOPS, etc.
- **The importance of 'Drills'** such as an unconscious diver should be simulated with all team members to simulate 'real time incident emergency'. This would be followed by review phase similar to post works phase where lessons learnt are documented and changes made to improve emergency response time.
- **Standby Equipment** that is certified and capable of meeting the requirement of emergency rescue situations (Strong Enough, Fast Enough, Tough Enough) should be identified and where practical, staged on site. This may include specialist tools such as robotics, drones, borescopes, etc.
- **Integration of technology**, use of tracking apps, virtual whiteboards to all stakeholders, digital watches or trackers with GPS and vital statistic monitoring in place.
- **Establishment of 'not to exceed' variance levels** (upper and lower control limits) for critical process parameters.

<u>Site Operations</u>

During the site operations, a communication plan is key to identify the responsibilities of each resource and keep all team members abreast of the progress. In this case, for a 24-hour activity, there should be at least two (2) daily update meetings, i.e., one for each shift, with the Project Manager attending both to allow for a smooth transition from day to night shifts. Documenting the updated progress and sharing with all stakeholders is key to inform the wider Team of the lookahead for the planned activities. Any member foreseeing changes to the planned activities must use this forum to signal said changes and re-plan as necessary. Key team members would assess and identify new variables such as new information or changes to process conditions by:

- Reviewing, monitoring and updating of risk assessment conducted in Pre-Works; this is essential in ensuring that any changes in the workplace have not introduced new hazards or changed hazards that were once ranked as lower priority to a higher priority.
- Execution of sitework activities and monitoring for change of relevant process conditions and variables such as environmental site conditions, pressures, temperatures, flowrates, levels in pipeline. Noting physical conditions of personnel can now be monitored with available technological tools, with monitors tracking heart rate, location, body temperature, etc. these can all introduce new time dependent risks during any operation where personnel access is difficult to reach (e.g., confined spaces).

<u>Mitigative/Preventative</u>

At this stage, the incident has occurred. Response time is critical to success of limited loss to no injury, so the Team must remain calm but be guided by the ERP. Correct assessment of the incident is an important factor as this drives the response actions that follow. Expert and professional team members must assess the situation and provide the correct guidance on the next steps. In the case of this hypothetical incident, what was driving the response time? Was the event still occurring? Could the event recur? Some important points to note:

- Implementation of emergency response and contingency response plans that would have been formulated and reviewed in Pre Works and Site Operations phases respectively. Within these plans the procedural and communication steps during an emergency should have been followed and the Responsibility, Accountability, Consulted and Informed (RACI) matrix adhered to allow engagement of all relevant stakeholders.
- Previous Drills from the Pre-works phase should be familiar to operations personnel and now being executed in a calm and proficient manner.
- During the incident, if the event was process related, the ERP could have included a possible way to eliminate any further hazard events from recurring by ceasing all operations in the vicinity –ceasing all operations and to isolate all energy inputs – electrical, mechanical & process. By ceasing all factors affecting the pipeline, the main hazard event can now be deemed no longer a risk to return and rescue efforts can now be implemented. Now, by reducing the risk of return of the hazard event, or even eliminating it, the rescue activity now carries a significantly lower risk and all efforts can now be made to rescue the missing personnel.
- Use of digital tools during the 'Live Emergency' such as mobile updates, digital white boards of the incident and live camera visuals and audio tools to all required stakeholders would assist during rescue efforts.

Post Works

The key learnings from this incident, are to capture the lessons and develop solutions to ensure this can be prevented. A routine activity has now resulted in multiple fatalities, which has now changed the regional risk profile for subsea activities in the region. That is, the likelihood of this event taking place has now changed from "Heard of incident in the industry" to "Incident has occurred in company." See Figure 7 below:

Consequence of failure (COF)	People (P)		Slight Injury	Minor Injury	Major	Single Fatality	Multiple Fatalities
	Asset (A)		Slight Damage	Minor Damage	Local Damage	Major Damage	Extensive Damage
	Environment (E)		Slight Effect	Minor Effect	Localized Effect	Major Effect	Massive Effect
	Reputation (R)		Slight Impact	Local Impact	Industry Impact	National Impact	International Impact
	Severity rating		1 Negligible	2 Minor	3 Moderate	4 Major	5 Catastrophic
Probability of failure (POF)	E Very likely to happened	Happens several times per year at location	Moderate	High	High	Very High	Very High
	D Likely to happened	Happens several times per year in company	Low	Moderate	High	High	Very High
	C Possible to happened	Incident has occurred in company	Low	Low	Moderate	High	High
	B Unlikely to happened	Heard of incident in industry	Very Low	Low	Low	Moderate	High
	A Very unlikely to happened	Never heard of in industry	Very Low	Very Low	Low	Low	Moderate

Figure 6: Risk Assessment Matrix Model of O&G Pipeline Integrity Management[17]

Key steps in this phase will include:

- Reviewing the accuracy of the risk assessment contributing to a Major Accident Hazard event and how it influenced emergency response. This includes identifying any gaps, root causes and lessons learnt such as restricting the number of personnel in the vicinity of the pipeline during operations to essential personnel only and questioning if these offshore operations could have been performed by robotics at a reasonable cost.
- From the post works documentation and sharing of lessons learned, toolbox talks, continuous improvement action plans should be shared within the organization. This also includes update of process assets such as MOC procedures for example. This will improve safety culture in the organization as well as provide a functional repository for future knowledge sharing.

It is important to perform validation of the root cause of the incident before we can develop and implement solutions. This would determine which gaps exist and where collectively the emphasis should be placed. Ishikawa or Fish Bone diagram can help identify Potential Root Causes leading to the Incident, but factors identified here need to be validated against the facts of the investigation, to determine which factor/s indeed did contribute to the main hazard event.

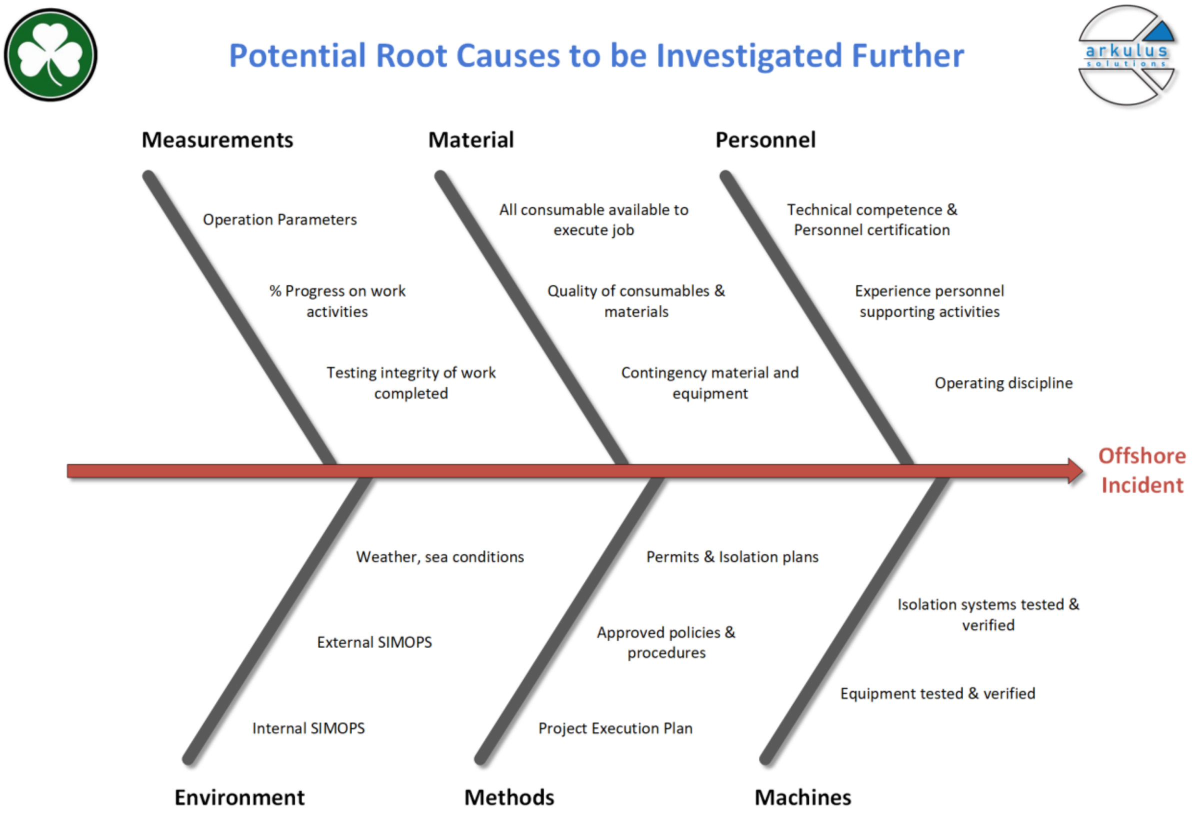

Figure 8: Ishikawa diagram identifying potential root causes.

For illustrative purposes *possible* solutions based on *possible* root causes, can include applications of the following: Process safety management tools and processes including Safety Critical Task Analysis, Human Factors Risk Assessment, methodology for contractor capability assessment, procedure for issuing permits for emergency response, Emergency Drills, Safety Critical Equipment listings/deployment etc. can be used and referenced to ensure risks are ALARP.

It should be noted that using ALARP principle allows organizations to set practical goals for risk reduction based on costs, time and complexity rather than being prescriptive. The ALARP approach allows organization to be flexible whilst supporting innovation, however, draw backs are that it requires value judgement and smaller organizations with limited budgets are likely to default to using manual intervention instead of more expensive equipment that makes the job safer. This brings into question a major issue regarding ALARP, with some companies switching to Continuous Risk Reduction (CRR) instead.

Conclusions

There are many tools that can be applied to the factors leading to the incident and setting up the right framework is vital. The following tools and techniques have been identified to address the gaps highlighted in this paper:

- A robust communication plan can also help provide closer feedback and may help prevent personnel from exposure to potential hazards being created by changing variables.

- Regular reviews and audits by independent experienced 3rd parties can also assist in identifying gaps and assist companies (operators and contractors) to follow best practices.

- Technologies including spatial modelling, thermal/laser imaging inspections, unmanned vehicles and others, pressure/temperature/flow monitors, may also be used to mitigate risks in day-to-day operations by facilitating comprehensive and timely analyses and diagnoses.

- Devices that track employees' GPS coordinates in high-risk areas can save critical time in locating people during emergencies. Wearable devices that collect data to predict how long employees can be in a work situation, especially those that are high-stress, before becoming fatigued, may be able to reduce the risk of human factors leading to a safety incident. New intrinsically safe trackers with heart rate monitors, GPS locations and communication can be synced to a central software system and provide real time feedback to a remote support team.

- Use of mobile devices as tools that can provide meaningful information in a timely manner while also increasing employee engagement; collection of incident data, near-miss reporting, audit report findings etc.

- New technologies exploited such as Big Data, analytics, mobile applications, cloud computing, enterprise resource planning, Governance, Risk, and Compliance (GRC) systems, are very important for risk management. There are also a number of risk visualization apps/programs, social media, data integration to the internet to gather real-time data, digital image processing and artificial intelligence to assist in decision making.

- An Enterprise-Wide Risk Management (EWRM) system will aid organizations in accessing cascade risks it covers many different aspects of strategy /operations/ projects/unforeseen risks including the interlinkages between the different risk levels and the strength of those interlinkages. EWRM systems can be tailored to an organization's risk appetite, to the extent of its risk capacity, i.e., how well it can control the risk and the duration of the risks are functional inputs (internal and external risks). As many risks are happening dynamically, it provides a framework whereby they can be captured and effectively managed, even if the unforeseen or unforeseeable risks happen, they will be able to be analysed, monitored and controlled thereafter. It is important to note the number of indicators: Key Performance Indicators (KPIs), Critical Success Factors (CSFs) and other metrics, in the EWRM help reduce the chances of unforeseen or unforeseeable hazards escalating into a Major Accident as risk identification is greatly improved.

- A resource such as a 'Risk Engineer' can greatly help reduce the gaps in industrial risk assessment through all the four (4) phases of risk assessment: Pre-works/Planning, Site works, Mitigative/Preventive Response, and Post works, which is usually performed by an already overextended Project Manager. Having a dedicated role to monitor the workflow, can help ensure governance and monitoring of the risk management processes. Additionally, a Root Cause Analysis (RCA) Facilitator to conduct RCAs to using PSM tools can add great value in the Post works; RCA facilitators will use problem solving techniques such as: Problem Solving A3s, Cause & Effect Mapping / Fishbone, TapRooT®, 5-Whys, Poka Yoke and Lean Six Sigma techniques to implement 'Kaizen' continuous initiatives within the organization. Visiting the site, a.k.a. the 'Gemba' walk, is always a good plan to get familiar with the job and provide great insight to the operations affecting or being affected by the project activity.

In most project lifecycles, we may never experience the tragedy or incident in the third phase of the workflow: Mitigative/Preventative Response Phase, but much like safety drills at the office or instructional videos in an aircraft before take-off, contingent and response planning should never be taken for granted as due diligence must be placed as early as possible, before an incident.

To sum up the narrative, we leave you with the words of Benjamin Franklin: *"An ounce of prevention is worth a pound of cure."*

References

1. IEC 61882, Hazard and Operability (HAZOP) Studies – Application Guide; 2016;
2. ISO 31000:2018 Risk Management
3. IEC 31010:2019 - Risk Management - Risk assessment techniques
4. Pitblado R, Turney R. 1996 Risk assessment in the process industries. 2nd ed. Rugby, UK: IChemE;
5. Hurst, NW 1998. Risk Assessment: The Human Dimension. The Royal Society of Chemistry.
6. Desai, Dushyant, ITC 2008. "Industrial Risk Assessment for Planning and Emergency Response: A case of Ahmedabad."
7. Deborah Keeley, Sandra Gadd and Helen Balmforth Prepared by the Health & Safety Laboratory, UK, Health and Safety Executive, 2003 "Good Practice and Pitfalls in Risk Assessment."
8. Xie, Xuecai, and Deyong Guo, 2018. "Human factors risk assessment and management: Process safety in engineering." Process safety and environmental protection.
9. Flight, Chontell, 2021. "Defeat Employee Complacency - Here's How." Web log. BIS Safety Software (blog).
10. AIChE. Guidelines for hazard evaluation procedures. 3rd ed. USA,2008: AIChE Centre for Chemical Process Safety.
11. Crawley, Frank; Tyler, Brian. 2015. HAZOP - Guide to Best Practice - Guidelines to Best Practice for the Process and Chemical Industries (3rd Edition).
12. Mannan, Sam; Lees' Loss Prevention in the Process Industries, Volumes 1-9, 2012 – "Hazard Identification, Assessment and Control (4th Edition)."
13. Canadian Centre for Occupational Health and Safety, Government of Canada, February 15, 2017. "OSH Answers: Risk Assessment."
14. Government of British Colombia, Ministry of Environment and Climate Change Strategy. March 31, 2021, "Guidelines for Industry Emergency Response Plans." Government of British Columbia. Province of British Columbia.

15. LeadingAge, leadingage.org. 2017. “Emergency Preparedness: Risk Assessment.” Washington, D.C., United States: Pathway Health Services, Inc.
16. Roam, Dan. Portfolio, Dec 31, 2009, “The Back of the Napkin (Expanded Edition): Solving Problems and Selling Ideas with Pictures”. Chapter 5 - The Six Ways of Seeing.
17. Munirah, M S Maziah, Libriati1, Z, Nordin, Y and Norhazilan, M N, February 2019, ‘Prioritization of the human health and safety loss factor subject to offshore pipeline accidents.’