Tampere University of Applied Sciences

Leadership and Risk Management in Nuclear Automation

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ABSTRACT

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The nuclear projects now a days adopted to more innovation and automated system to enhance the safety and reliability of the project. However, the reliability and success of the nuclear project depends largely on leadership and managing risks within the project. This thesis is focused on correlation between the risk associated with leadership considering human potential impacting on the nuclear automation project.

The study describes about the nuclear automation project, where it has been observed many times company is underperforming due to gaps within organisation, due to improper leadership, lack of focus on human potential involved, lack of procedures and instructions, training, and understanding process by the people involved in the nuclear automation project.

The research is based on both qualitative and quantitative approach with survey, discussions, and interviews as a source of primary data collection from the technological leaders, experts, and engineers who are involved in nuclear automation project and leading the project development process. Also learning experience from various nuclear project failure cases to understand the risk associated to a nuclear business.

The risk and gaps identified in the thesis define a risk matrix based on analysis done for leadership requirements and risk management. Also provide conclusion, recommendation, and discussion to define clear path for a leader for successful project execution to avoid overrun of budget and failure of timeline and schedule of a project.

Key words: leadership, organisation, risk, assessment, human factor, human potential, analysis, matrix, training, thinking.

CONTENTS

1 INTRODUCTION

The objective is to understand the deep-rooted philosophy of leadership competence or characteristics which drive a person to lead a nuclear automation project successfully. This is to make self-realized to become a leader, inspiring self, and then inspiring the people around.

The thesis focuses on theoretical aspects of process describing the leadership, human factor involved in various safety and risk assessment methodologies used in nuclear automation project like failure mode effect analysis or cause and consequence of failure or probabilistic risk analysis during the entire nuclear power project lifecycle basic design phase, details design phase, offsite testing phase, on site installation phase, commissioning phase and operating phase. Readers will understand the importance of leadership to execute safe and successful nuclear automation project.

The thesis study identifies the gaps between safety significance of nuclear power project with respect to the human potential and self-leadership. The inputs are collected through survey, discussion, and interview of different experts in nuclear automation business, from different books, journals, scientific articles, learning from failure of previous nuclear project, and data from severe accident analysis.

Research objective

What are the gaps or disparities in leadership (leading self and others), human performance, human potential, human behaviour, and communication which is responsible to overlook important aspects of risk associated in nuclear business which may lead to loss of time, increase in cost, loss of trust or cause fatal future failure of a nuclear project?

2 LEADERSHIP MANAGEMENT

The global leadership crisis as per the study made by Harvard business review press (Rasmus. H, 2018) observed 77% of leaders anticipate that they are doing a good job for people engagement, though 88% of employees say their leaders fail to engage enough. There is also a high level of dissatisfaction in the workplace: 35% of employees would vote to see their leaders fired. There is an enormous waste of human talent. The organisation and leaders failed to identify the human needs, purpose, connection, and genuine happiness in the workplaces.

There is a high need for developing leaders by focusing on the three core mental qualities based on emotional intelligence (Daniel. G, 2013), that is mindfulness, selflessness, compassion.

2.1 Leadership

The first trait of leadership is to understand your own potential and limitation. The effective leadership comes from the following potential (Alistair. M, 1999).

- Perseverance
- Self-knowledge
- Willingness to take risks
- Willingness to accept failure
- Willingness to accept challenges
- Consistency
- Ability and desire to learn.

The effective leadership comes from knowing the following limitation.

- Factors limiting thoughts and thinking
- Factors limiting to foresee the failures within team and organisation
- Factors limiting to learn and understand the needs
- Factors limiting to decisions.

2.2 Discovering leadership

Discovering leadership within self is about self-transformation, preparing to become inspirational for others and motivate them by creating the context for others to find their own meaning, drive, and sense of association within this existing engaged role in an organization. Even leadership practices remain also same for the digital era leadership. The new era of digitalization has made leaders to delegate online which is again accomplished successfully with effective communication competency in addition to know the virtual environment of workplace. So, discovering leadership is to learn and accepting *change within self,* which is an important attribute of a good leadership, that count for strong adoptability. Leading people is being honest to motivate people by sharing honest unbiased approach to them which built strong trust within team.

2.2.1 Leading self and motivating others

The self-awareness (in-depth awareness) leading to self-motivation, help to transform one's own thoughts. Knowing self is one of the key aspects or learning for being a good leader which means leading self and then leading any task or people. To fix all these needs, self-understanding and knowing own potential is necessary.

Figure 1 illustrate the leadership model, and it represents that the first step to lead is to define leadership insight to understand self-motivation with self-awareness, and self-regulation to bring out self-leadership in action to make impact on the team and individuals. So, strategic leadership is key for leaderships to drive the people with motive, influence productivity, and increase quality of work output.

The key things to motivate others are mentioned below.

- Strengthening the emotional intelligence skills
- Shared purpose
- Compassion
- Empathy
- Be honest and grounded.

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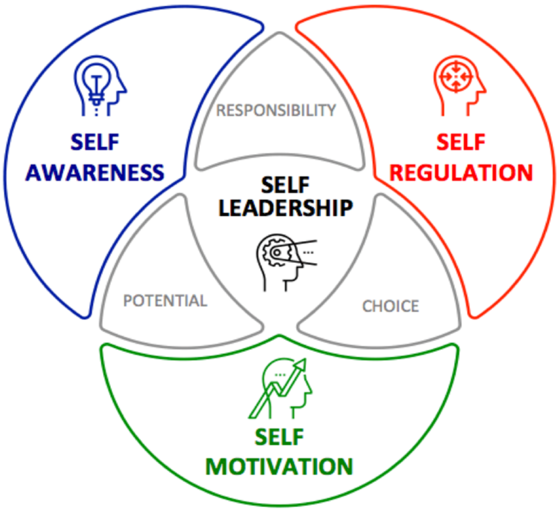


FIGURE 1. Self-Leadership model (Foley. L, 2019).

2.2.2 Leading team

With my experience while leading some teams, I observed that honest approach and clear communication helps and brings good cooperation which develop team spirit. Developing a sense of acceptance for each other with in a team and to value individual thoughts and ideas, then sharing honest feedback to the team and individual also help to identify the need.

As mentioned in figure 2 (Rasmus. H, 2018), it is described with different layers of leadership. Leaders should start leading self, then leading people, and leading organization with three major qualities to make a change within team building, team spirit and team motivation is *mindfulness, selflessness, compassion*.

Self-leadership begins from mind and it is about managing own thoughts, behaviors, and actions. The mind shapes the thoughts, then the thoughts lead to action and the action becomes our habits, thus it shapes the life. So self-leadership is the foundation for effective and productive leadership.

FIGURE 2. Leading team from the mind of the leader (Rasmus. H, 2018).

2.2.3 Competence management

Competence management (Maria. V, Klas. E. S, Gregory. P, 2007) is one of the major functions for any organization to succeed in any venture. The competency mapping in an organization help to identify the required skills and developing new skills for individual or team with an objective to align organizational goal with individual goals.

However, it is also important to assess own level of our competencies. Competency development is mainly for effective communication as a core or critical competence required to proceed for developing other competence and skills at individual level or organization level. Handling competence development is also a part of change management. Therefore, effective communication is one of the key factors necessary for implementing and handling change.

Organization is changing with the change in demand and new trends of business models. So, the focus for changing individually based on knowledge, skills and mindset keeps a strategic requirement to align to adopt the different stages of change and learning.

It is also observed within some organization that they keep training lesson and session to fulfil or maintain the compliance requirement to showcase authorities that they pursue people development. However, the well-organized training or model for competence development can change the entire success pathway of an organization.

2.2.4 Coaching skills

As (Herminia. I, Anne. S, 2019) the companies have realized that managing people or leading people is not about command and control, instead coaching model plays an important role in problem solving and encouraging people by asking questions and providing support or guidance.

The leaders as coach are one of the attributes to lead people. *To be a coachee, to be a coach, and to be an observer,* there are three functions important to understand the position of a coach and develop own sense for understanding different viewpoint about coaching skills. Table 1 define the three functions of the coaching skills along with learning from those functions.

TABLE 1. Coaching functions and learning (Herminia. I, Anne. S, 2019).

Function	Learning
To be a coachee	Good communication skill to explain the problem etc. Coachee owns the solution by self
To be a Coach	Good listening skills, questioning skills etc. Coach does not give answers or advice, ask open questions.
To be an observer	Good listening skills, honest feedback, or approach etc. Managing feedback process.

Figure 3. describes about four steps GROW model (John, W. 2019) which is a tool used for developing coaching skill within leaders to become more skilled in listening, questioning, and drawing insight out of the people they lead. It is about finding the options rather advising. Implementing coaching skills requires a very good communication skill and patience. Appropriate question is a very

important aspect to understand the problem with clarity and there should be no interference from own emotional situation

The tool useful for the coaching skill is GROW model (John, W. 2019) (from mindtool.com).

FIGURE 3. Coaching model GROW (John, W. 2019) (from mindtool.com).

2.3 Leadership in a nuclear power project (NPP)

It is well explained (Clark, C, R., Kazennov, A., Kossilov, A., Mazour, T., Yoder, J, 2004) in IAEA-CN-114/F-8 that experience of leaders realized both within and outside the nuclear industry, the below mentioned factors are the effective mechanisms to improve human performance.

- Management sponsored and leadership driven improvement initiatives.
- Improvement strategy based on business planning processes that integrates human performance.
- Communication to support excellence in human performance.
- Personal development with systematic approach like training etc.
- Effectively briefing job and responsibilities.
- Identification and observation programmes focused on removing the gaps and barriers to result in excellent performance.

As per the Nuclear Energy Act (990/1987), the nuclear facility shall have a management and quality system. The licensee of nuclear project is responsible of facility's safety, planning, functionality, effectiveness, and continuous improvement of the management systems and quality management systems. In context of leadership in nuclear power project following are the requirement for leadership.

1. For the leaders in nuclear projects, it is important to know the scope from the STUK YVL A.3 guidelines "leadership and management for safety", and the details are mentioned in appendix-2 and appendix-3.

   The important aspects of the organisational requirement in nuclear power project (NPP) leadership are based on following.
   - Nuclear and radiation safety.
   - People & environmental safety, security, and emergency response.
   - Nuclear safeguard at all stages of the nuclear energy like engineering, construction, and operation.
2. Leaders to understand the different concept of development and integration of objectives required for leadership management (as per International Atomic Energy Authority (IAEA) standard GSR Part 2:2016).
3. Leaders to focus and understand the development of the management system with respect to the following.
   - Quality management system for safety system.
   - Importance of requirement of quality assurance plan.
   - Organisation procedure and instruction to develop process for safety system.
   - Importance of project management plan.

2.3.1 Decision making and strategic thinking

Time critical decision making (Luce, R., D., Raiffa, H. 1957) (Raiffa, H.1968), there are relevant cognitive aspects analysed for higher cognitive process and high level of models are available for time-critical decision making. It is also discussed clearly that one model does not dominates the other, however compliment to one another as shown in figure 4 and figure 5 (Lawson. J. S, 1981). Focus and the common measures are analysing the situations before making decision. The general process follows one among the three steps.

- If the circumstances or the case matches to a previous situation, then the choice is to choose a standard solution based on experience, and result which is applicable to the case.
- If the circumstances or the case matches partially to any previous situation, then the choice is to gather more information to map it to at least one from the previous situation based on experience.
- If the circumstances or the case does not match or is new, then the choice is to choose the simplest solution form from experience and if the solution does not work then find another solution.

Figure 4 illustrate about OODA loop (Boyd, J. 1987) (Lawson. J. S, 1981) which suggest observation, orient, decide and action to search out a solution to a real-life situation. The inputs are collected from the environment as information, and by interaction etc. Then by orientation loop it is analysed as a component of process to satisfy the required or specific expectation. The next step is to take a decision over the situation which is followed by an action which led to implementation of the decision. The feedback is an integral part of the OODA loop (Boyd, J. 1987) (Lawson. J. S, 1981) which verifies the decision is correct or not.

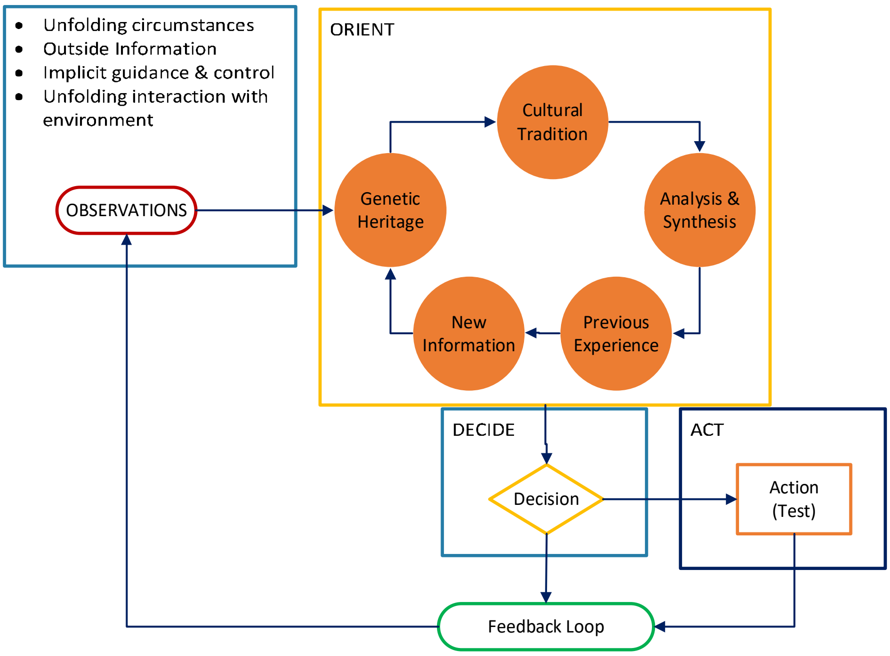


FIGURE 4. OODA loop (Boyd, J. 1987).

Figure 5 is the adopted model from OODA (Boyd, J. 1987) (Lawson. J. S, 1981), it represents that the data or information flows between the environment and own forces. The model states that some desired result that command centre (environment and own forces) wanted to attain by extracting information from environment which is compared to the desired state and if there is a deviation found within the desired state and the extracted state, then the command analyse decide to reach the desired state. Once it is finalised then the action is implemented to execute the decision and it is communicated to the own forces.

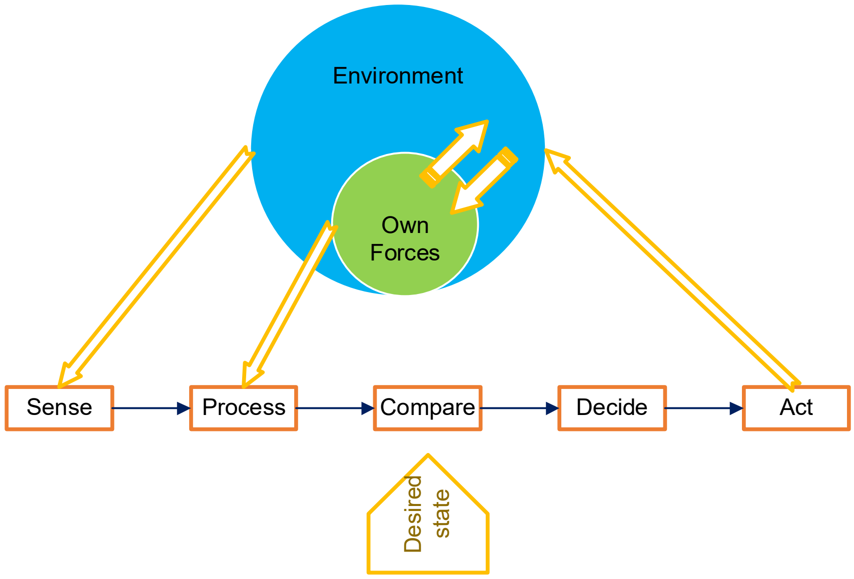


FIGURE 5. Lawson's control theory model (Lawson. J. S, 1981).

Strategic thinking

Scenario planning is a tool for strategic thinking (Schoemaker. P. J. H, 1995). Strategic planning is a tool which leaders can use to create a scenario to generate a trend and identify the uncertainties. This help in making decision with compensated errors. The defined knowledge with what we know depends on the human factors like over confidence, under or over predictions, and the tendency of looking for some confirmative evidence. Scenario planning is important to understand the collective ignorance towards our own understanding of believes and thoughts.

Scenario planning majorly outlined in figure 6 the following steps.
Step 1. Define focal questions for the scenario.

Step 2. Identify certain & uncertain drivers of change over selected timeframe.

Step 3. Develop scenario based on drivers.

Step 4. Developing new strategies together with existing strategies.

Step 5. Test existing & proposed strategies against scenario.

Step 6. Produce an action plan commit to be implemented.

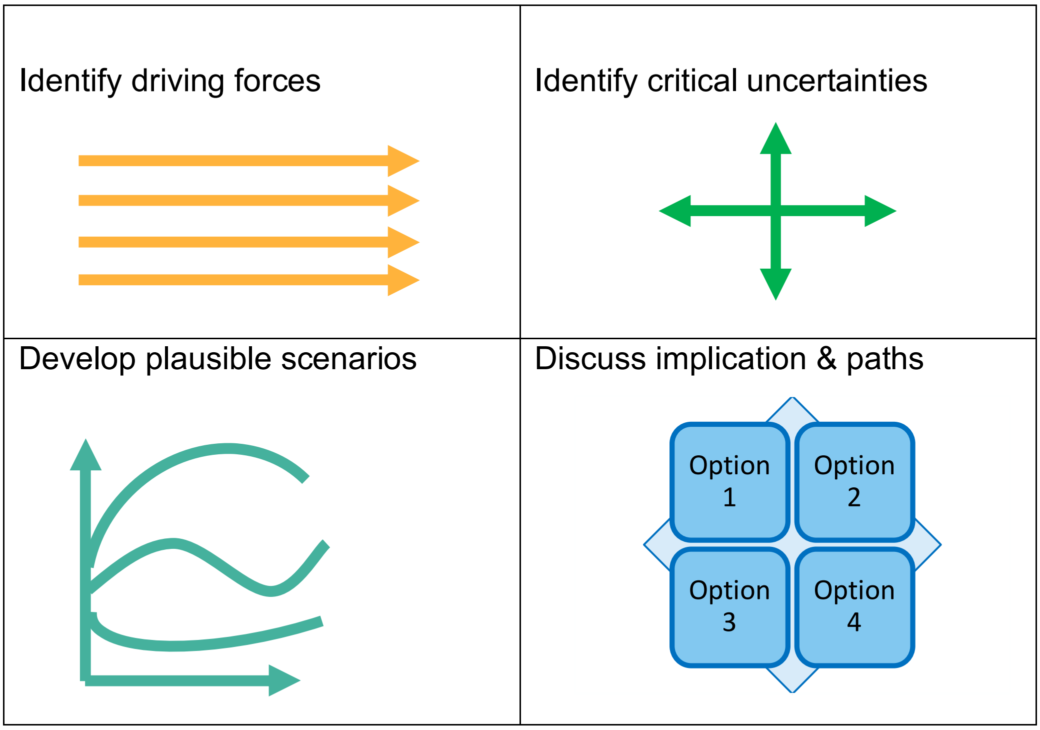


FIGURE 6. The scenario development process and approach (Schoemaker. P. J. H, 1995).

For cultivating a strategic mindset (Schoemaker. P. J. H, 1995), the important question is “How to improve strategic thinking skills?” The strategic mindset is to find out the way to think instead of what to think. Strategic thinking also brings or discover future success with new opportunities, and address to any or all future challenges.

Asking more strategic question can develop planning skills, adoptability, and future options. Strategic skills are often upgrade up over the time with the subsequent steps.

- Practicing skills and learning new skills.
- Training for more development.
- Communication skills development.
- Design thinking skills development.

3 HUMAN FACTOR

The human factor is one of the key factors in nuclear power project for keeping the reliability of plant, it also defines the continual improvement within the man and machine synchronously working together. Nuclear automation system which is known as complex system must be well engineered to make it more interactive systems between man and machine (Swaton. E, Neboyan. V, Lederman. L, 1987).

3.1 Human behaviour and impact

As per Swaton. E, et al. (1987), role of human factors is being significantly analysed nowadays because the reason for occurrence of incidents or events has been found majorly due to human factor.

-In Japan, an occurrence of an incident for a databank must be reported within 48 hours, and a full detail report within 30 days. The percentage of human error for the total number of incidents is approximately 10%. More than half (54%) of the cases caused in automatic shutdown; 15% caused in reduction of plant power generation, and 31 % had no impact or effect. Half (51 %) of the causes of human errors were due to insufficient maintenance, and 29% were because of improper operation. One estimation, by a Belgian expert, showed that out of 40 scrams for seven reactors, 70% had a human related factor. An in-depth statistical analysis which was performed by Electricite de France (EDF) showed relatively few errors during the night when there is little activity, and during the lunch hours. The foremost common kinds of errors included omissions and delayed operations. As for mechanisms of errors, the foremost common are forgetting to perform an operation and therefore the failure to spot the proper operation, together with a bad diagnosis of the state of the system.

Human error can contribute substantially to system failures consequently causing into a big disaster. Operational experience in nuclear power plant shows that human error has a considerable proportion of safety-related events. However, it is also true that the human factor as tool will be very effective if there is a methodical process developed for handling the situation within the plant. Therefore, an effective and efficient interface of man and machine is important not only to stop human errors but also to support the operator in managing with the unforeseen events. Human reliability is understood as factors based on qualitative as well as a quantitative term (Swaton. E, et al. 1987).

- Qualitatively factors describe purpose for successful human performance and activities necessary for plant reliability.
- Quantitatively factors, it demonstrates the data on failure rates or error probabilities of failure as analysed in the probabilistic safety assessments.

3.2 Human factor performance

Over the past few decades, the automation system modernisation has negative influence on human performance as human brain has substantially stopped thinking by its own rather depending on the digital gadgets for performing the activities. So, there is a need of defining human factor (shown in table 2) involvement which deals with the following interface between human and machine.

TABLE 2. Human factor and automation.

	Human factors and computers
Identification	Humans are far superior then computer system to recognising patterns which may be reason for an occurrence of an event. Humans can formulate any incomplete information based on the experience. The strength of computers lies in fast calculation, measurement sensing and validation, and in handling complex computations. For identification, computers mainly depend on logical processes based on given rules and data.
Analysis and interpretation	Computers can process complex algorithmic, handle fast and efficient operations in reliable manner, but computers have limited capacity for application based on experience-based operations. However, humans can think, simplify

	across samples, using judgement, can take decisions with experience, and implicit knowledge.
Comparisons	Processing and memorise large amounts of information & data, and comparing them based on pre-defined guidelines, is a strength of the computer-based computations. However, humans can compare any data, make use of data and for calculation & comparisons, proving more on experience-based information.
Planning	Though computers are fast and can storage large information and computation which is an advantage, however strength of the human quickly adapt to existing procedures to suit the situation and can even prepare new design new procedures if so, needed for the plant and its safety. In general, computers can only function efficiently and reliably within limited frame of problems. But humans can control any kind of the system and situations compare to computer.

Systematic approach for human performance is very important. As per IAEA-TECDOC-1204, (2001), in technological environment, technical skills related to nuclear technology is considered basis of successful human performance, however it has become progressively clear that there is a great requirement of focus on maintaining and improving 'soft skills' such as leadership, communication, performance assessment, training, teamwork, coaching, and mentoring. Approach to this need is defined as below.

Performance = Knowledge + Skill + Attitudes + Opportunity + Effort + Motivation

The performance can be monitored, and change can be implemented as mentioned below.

Identify performance deficiencies	Respond to change environment
• Formal root cause analysis • Supervision • Self-assessment • Observation	• Review the organization’s strategic vision and goals • Identify changes needed • Performance and in business processes implementation to achieve these strategic goals.

4 RISK MANAGEMENT

The concern of risk management has continuously increased in nuclear power projects and not only limited to nuclear power project (NPP) but also in other critical projects too. Nuclear power projects have a higher level of risk and complexity, therefore if the risk is not managed then it results in greater possibilities of cost overruns and delay in project due to conflict in schedule. The goal of risk management is to improve project performance by systematically identifying and assessing project risks, developing strategies to reduce or avoid risks and to maximize opportunities for successful completion of the project (Barry D. S, 2017).

To address risk, various risk management methodology is used and some major mentioned in this thesis used for nuclear power project (NPP). And the thesis investigates the multiple dimensions of risk that are external, internal and has large impact on the nuclear power project (NPP) during all phases.

4.1 Risk management

Primary objective in a nuclear power project (NPP) is nuclear safety. Nuclear safety-related risk management is the minimum requirement which all nuclear power project (NPP) need to achieve. The risk framework as shown in figure 7 (IAEA-TECDOC-1209. 2001) is prepared to describe and understand the involvement of various parties defining the requirement of the safety in a nuclear power project (NPP).
Many of the identification processes, measurements, and management tools are strictly qualitative in nature and dependent on the judgment of the managers involved.

4.1.1 Risk management framework

For each issue or event requiring a decision, managers can benefit from adopting a systematic approach to identifying the potential risks, looking specifically at the sector in which the proposal falls, but also looking at the intersection with the other sectors. The idea is to try to identify all the consequences of a particular issue or event, to find an optimal decision set to minimize adverse effects and maximize social and business objectives in a cost-efficient manner. Figure 7 shows about the risk management framework providing this systematic approach.

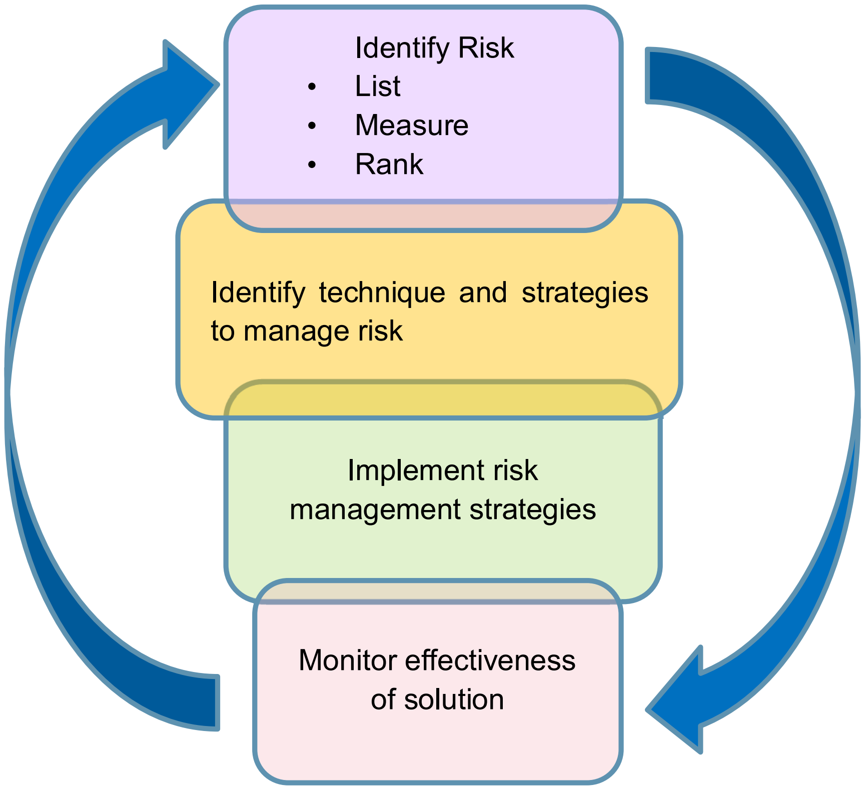


FIGURE 7. Risk management framework (IAEA-TECDOC-1209. 2001).

4.1.2 Risk management environment

The nuclear power project (NPP) project risk assessment requirements are defined by these sectors intersect one another as illustrated in Figure 8. It represents about the responsible, decision makers, regulators, users, and operators for a nuclear power project.

The human factor performance management is also shown in appendix 4 (Edmonds. J, Mitchell. J, 2016) as a mind map to illustrate the factors affecting individual then consequently affecting the project.

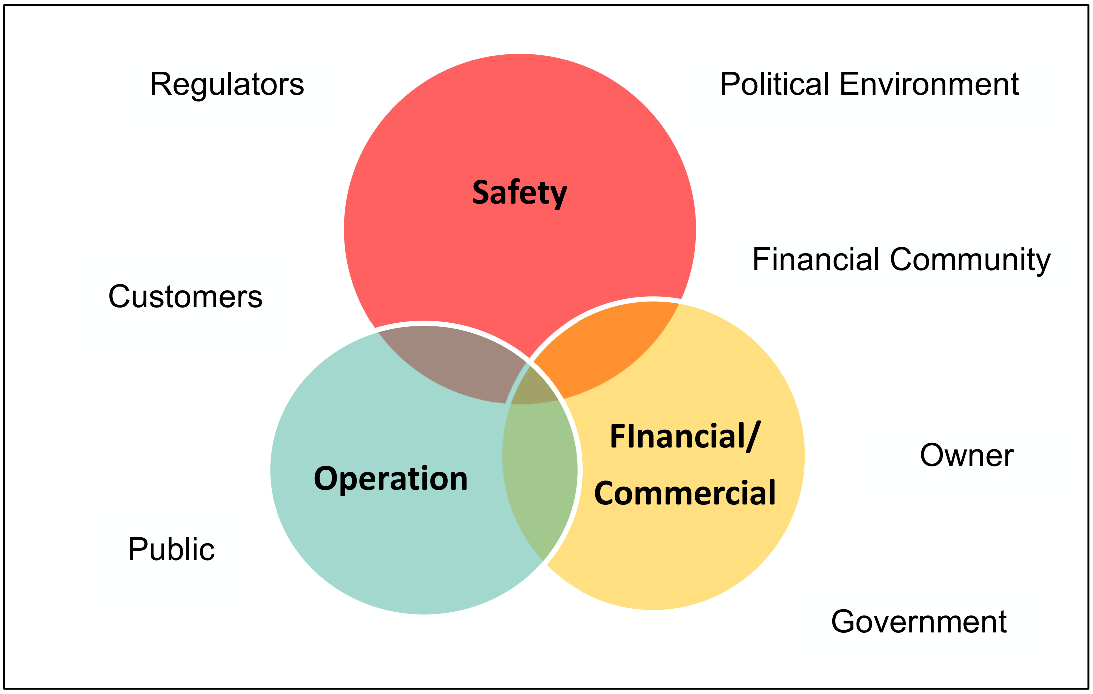


FIGURE 8. Risk management environment model for a nuclear power project (www.researchgate.net).

4.2 Automation project lifecycle stages

The nuclear automation project is defined in a life cycle (as per IAEA Nuclear Energy Series NR-T-1.18) in different stages to keep a track on the different milestones to be achieved during the project execution. The designer and supplier organization who is primarily responsible for developing the basic and detailed design associated with a nuclear reactor plant, as well as maintaining design codes and methods and having specialized knowledge of all the systems and components important to safety. As per nuclear regulatory commission (NRC), the typical nuclear power project life cycle phases are shown in this picture 1.

PICTURE 1. Typical nuclear power project life cycle (IAEA Nuclear Energy Series NR-T-1.18).

The standard life of a nuclear power plant is 60 years (sometimes up to 20 years of extension) and decommissioning cycle of 30 years.

The automation life cycle as defined from automation-01 to automation-19 of a nuclear automation project is shown in table 3 (source IAEA). The planning, basic design, detail design, integration, validation, offsite testing, installation, onsite testing (non-nuclear commissioning & nuclear commissioning) then operation of nuclear plant.

TABLE 3. Derived nuclear automation project life cycle (IAEA-TECDOC-1305, 2002).

Stage No	Project stage description	Project Phases
AUTOMATION -01	Overall, I&C planning	Phase 0
AUTOMATION -02	Overall, I&C requirements specification	
AUTOMATION -03	I&C Architecture planning	
AUTOMATION -04	I&C Architecture requirement specification	
AUTOMATION -05	I&C Architecture design	
AUTOMATION -06	I&C Architecture preliminary validation	
AUTOMATION -07	System Planning	Phase 1
AUTOMATION -08	System Requirement Specification Elaboration	
AUTOMATION -09	System Specification Elaboration	Phase 2
AUTOMATION -10	Preliminary I&C System Validation	
AUTOMATION -11	Hardware and Software Detailed Design	Phase 3
AUTOMATION -12	System Software and Hardware Procurement	
AUTOMATION -13	System Integration	Phase 4
AUTOMATION -14	System Validation	
AUTOMATION -15	Off-site architecture integration and validation	
AUTOMATION -16	System Shipping	Phase 5
AUTOMATION -17	Onsite Installation	
AUTOMATION -18	Non-nuclear commissioning	
AUTOMATION -19	Nuclear commissioning	

4.3 Automation verification and validation (V&V) framework

4.3.1 Automation lifecycle and V&V model

Verification & Validation Automation lifecycle V-Model

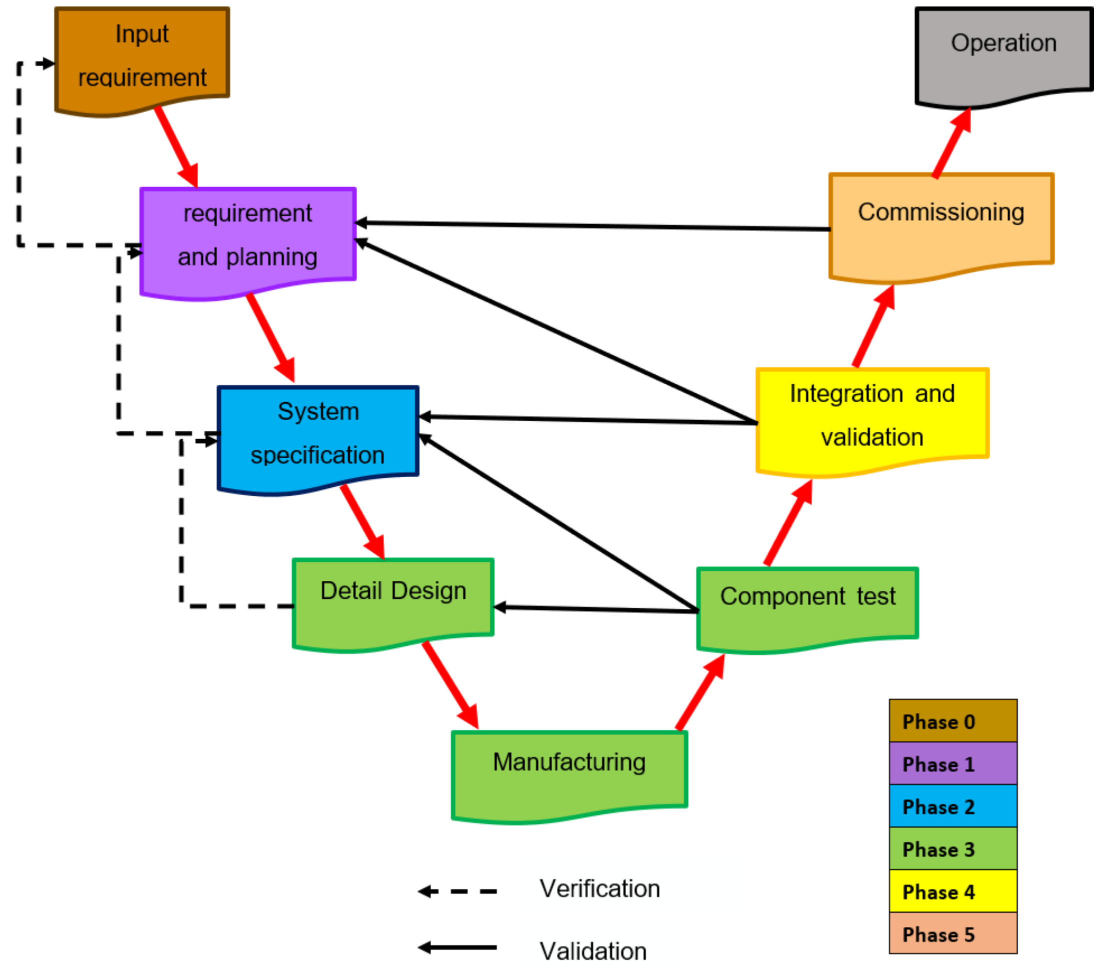


FIGURE 9. V&V model for a nuclear automation project (Pesola. J. P, 2010).

Verification in nuclear automation project means it is a measure, which aims at ensuring that the product is realised as specified or intended.

Validation in nuclear automation project means it is a measure, which aims at ensuring that the product is suitable for its purpose or use.

The V-model as shown in figure 9 (Pesola. J. P, 2010). is a higher-level concept representing the relation between general design, phase of I&C system and corresponding verification & validation activities to reduce the amount of error during different phases of project.

The role of the V&V team leader plays an important role of verifying and validating the process and design as nuclear power project is most sophisticated and technologically advanced sector and sets a very high & demanding safety requirement. The V&V process ensure a safety design by verifying in different phases of project during the engineering design basis, construction, commissioning and then operation to eliminate the possible failure or wrong design in the system.

To prevent the repetition of nuclear incidents and accidents, such as Chernobyl or Fukushima, ensuring safety of modern nuclear power project (NPP) is the highest priority for the nuclear industry. First and foremost, safety is accomplished by a complex of process systems and the safety buildings and structures that are part of the nuclear power project (NPP) design, construction, and must prevent or mitigate any possible equipment failures or operators' mistakes and, under any conditions, under any environmental influences by fulfilment of the safety functions. The results of V&V activities are handled by the various processes like review, analysis & test methodology and quality process mostly through the quality control at the equipment (component level), by qualification as qualification evidence at the system level and by the licensing at the plant level (Vladislav. G, Galina. K, 2018).

4.4 Failure mode and effects analysis (FMEA)

Failure mode and effects analysis (FMEA) model (Pinnarat. N. Santirat. N. & P Adisak. P, 2014) for the risk assessment is a tool which is very much useful to do failure assessment for industries like nuclear, aerospace, chemical, power plant etc. The power station needs reliable equipment and operation for better performance. And Failure mode and effects analysis (FMEA) tool as shown in figure 10 is also useful for system engineering, design & process engineering as the analysis reduces the probability of occurrence of failure and improve the plant performance & availability.

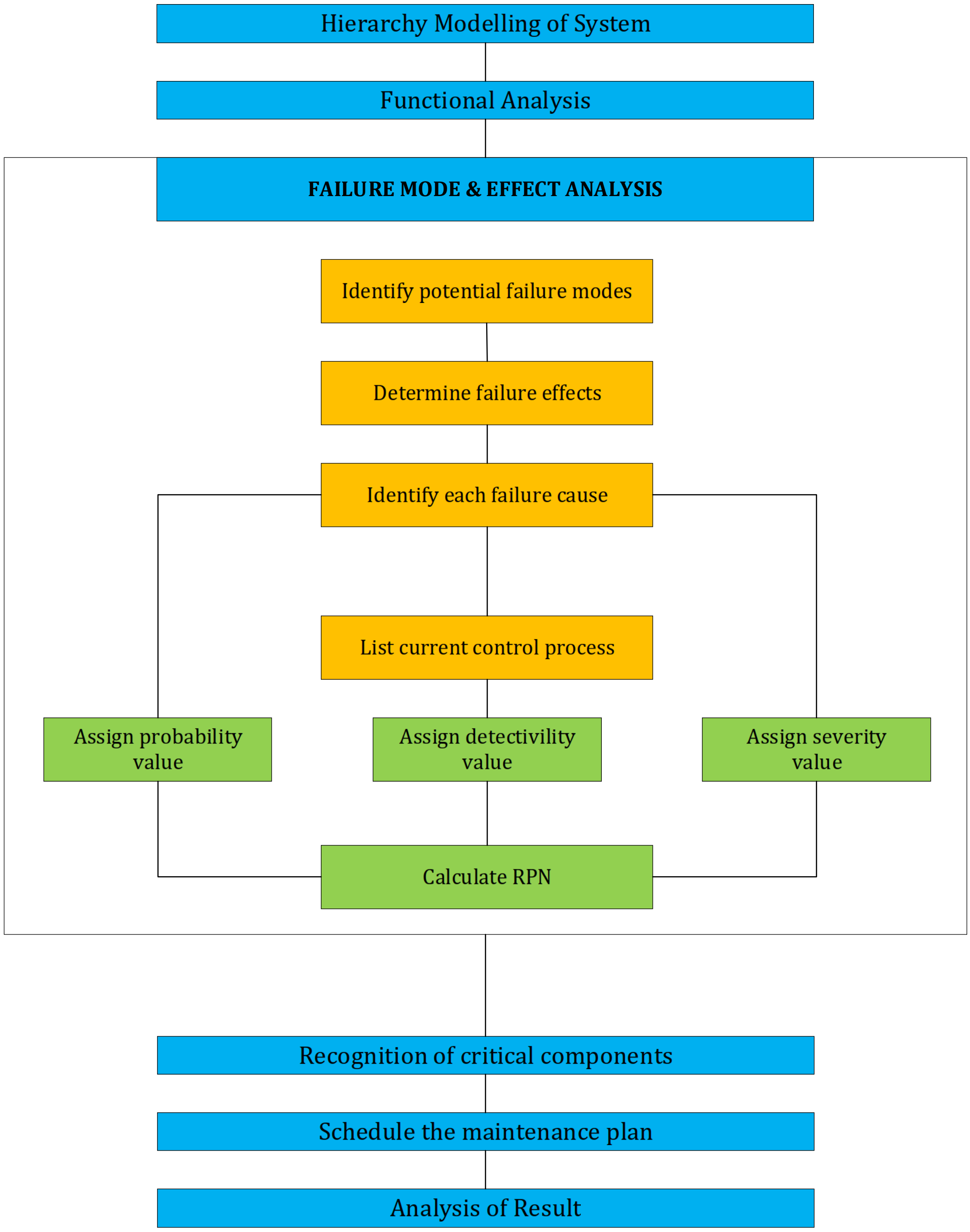


FIGURE 10. Failure mode and effects analysis (FMEA) process flow chart (Pinnarat. N. Santirat. N. & P Adisak. P, 2014)

4.4.1 Risk analysis method

Parameter used for Failure mode and effects analysis (FMEA).

1. Severity (S), occurrence (O) and detection (D) with failure cause matrix
2. Risk Priority Number (RPN) calculation

4.4.2 Severity(S), occurrence(O), and detection(D)

The details of parameter for severity, occurrence and detection are shown in table 4, table 5 and table 6 respectively along with effect and rating for the parameter measures.

TABLE 4. Severity rating criteria of a failure in failure mode and effects analysis (Ford motor reference manual, 1988).

Effect	Severity	Rating
Dangerous	Failure without warning. It is probable failure of operation	10
Serious	Failure with warning. It is potential failure of operation	9
Very High	The system is inoperable	8
High	The system may not operate, equipment damage	7
Moderate	The system may not operate, minor damage	6
Low	The system may not operate, without damage	5
Very Low	The system requires repair and degradation of performance	4
Minor	The system requires repair and minor degradation of performance	3
Very Minor	Minor effect on product or system performance	2
None	No effect	1

TABLE 5. Occurrence rating criteria of a failure in failure mode and effects analysis (Ford motor reference manual, 1988)**Error! Reference source not found.**.

Effect	Occurrence	Rating
Extremely high, failure almost inevitable	≥ in 2	10
Very High	1 in 3	9
High (Repeated failures)	1 in 8	8
Moderately High	1 in 20	7

Moderate	1 in 80	6
Low	1 in 400	5
Very Low	1 in 2000	4
Remote	1 in 15000	3
Very Remote	1 in 150000	2
Nearly impossible	1 in 1500000	1

TABLE 6. Detection rating criteria of a failure in failure mode and effects analysis (Ford motor reference manual, 1988).

Effect	Detection	Rank
Absolute uncertainty	Cannot detect potential cause of failure mode	10
Very remote	Very remote chance to detect potential cause of failure mode	9
Remote	Remote chance to detect potential cause of failure mode	8
Very low	Very low chance to detect potential cause of failure mode	7
Low	Low chance to detect potential cause of failure mode	6
Moderate	Moderate chance to detect potential cause of failure mode	5
Moderate High	Moderately high to detect potential cause of failure mode	4
High	High chance to detect potential cause of failure mode	3
Very high	Very high chance to detect potential cause of failure mode	2
Almost Certain	Almost certainly detect a potential cause of failure mode	1

4.4.3 Risk criticality and RPN calculation

The risk priority number (RPN) is calculated to identify the criticality associated to the system or the equipment (Basu. S, 2017). RPN calculated for all component and sub system as mentioned in risk break down structure.

The RPN is calculated based on the following parameters.
S - Severity
O - Occurrence
D – Detection

RPN = (S x O x D)

The calculated RPN (Basu. S, 2017) gives the qualitative analysis to evaluate the critical system or equipment and based on criticality of the system the corrective action or preventive actions are defined to mitigate the risk. Thus, reducing the RPN for critical system or equipment. It is also important that experience and learning from the previous failure rates and with consulting to an expert to define the value for the severity, occurrence, detection to calculate the accurate RPN. This will ensure that the accuracy of the analysis is high and more precise.

4.5 Common cause failure (CCF)

In nuclear automation system, common cause failure (CCF) analysis is defined as the events which causes multiple failure due to occurrence of shared causes or it is also set of dependent failures in which two or more component fault state exist due to a shared cause. Common cause failures analysis is used for risk and reliability analyses through the framework developed for common cause failure events (IAEA, Training) (ISO 26262, 2017).

Probabilistic safety assessment (PSA) is now a days widely utilised tool for safety analysis beyond design basis analysis. With recent studies for PSA’s. it is observed that common cause failure is more significantly responsible to core damages condition.

Dependent events caused due to two independent events P(A) & P(B) as illustrated in figure 11 shows that how independent events can create a dependent event and can impact one or more component.

Dependent events, which define the interdepend able consequences.

P (A & B) > P(A) * P(B)
P (A & B) = P(A) * P(B/A)

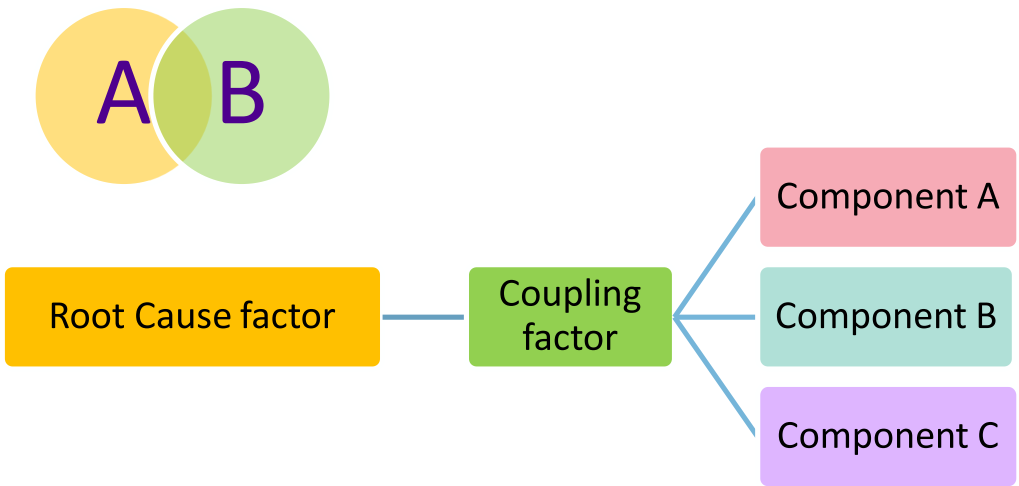


FIGURE 11. Dependent failure for the I&C system (source IAEA, Training) (ISO 26262, 2017).

Shared causes of common cause failure are divided into 2 elements (source IAEA, Training) (ISO 26262, 2017).

1. *Root cause factor* in figure 11 is considered the simplest cause of failure of an equipment which can be rectified by preventing the occurrence of the similar faults like.

- Hardware
- Human
- Environmental
- External to the plant.

2. *Coupling factor* in figure 11 is the common or shared causes impacting multiple equipment’s susceptible to failure.

Functional coupling	• Equipment connected • Equipment non connected
Spatial coupling	• Spatial proximity • Equipment linked
Human coupling	• Individual • Team

Strategy to reduce occurrence of root cause

- The occurrence of root causes can be reduced by increasing reliability of each item by installing additional reliable and robust components.
- Environmental control can be achieved by ensuring that operating environment is within design constraints, reduce shock-like exposures, diagnostic testing and coverage.

Strategy of reducing occurrence of coupling factors

- Introducing separation and redundant items (physical, functional, electrical).
- Implementing diversity in hardware and software
- Reducing complexity and simplifying architecture along with design, to reduce unidentified couplings.

4.6 Other general defensive strategies

There are other general defensive strategies used or defined during the development of the nuclear automation project. This strategy is related to internal processes which is maintained within quality framework.

Strategy	Description
Barriers	Building division and physical isolation that tends to confine and restrict a potentially damaging condition.

Personnel Training	A programme to ensure that the engineer, worker, operators, and maintainers etc. are familiar with procedures and can follow them during all conditions of operation.
Quality Control	A programme to ensure that the product is in conformance with the documented design and according to approved procedures, standards, and regulatory requirements.
Redundancy	To increase the reliability and availability of plant and equipment, additional, identical, redundant components added to a system for the purpose to perform a given function when exposed to a given cause of failure.
Preventive Maintenance	A programme of applicable and effective preventive maintenance tasks designed to prevent premature failure or degradation of components.
Monitoring, Surveillance Testing, and Inspection	Monitoring via alarms, frequent tests, and inspections so that failures from any detectable cause are not allowed to accumulate. This includes special tests performed on redundant components in response to observed failures
Procedures Review	A review of operational, maintenance, and calibration test procedures to eliminate incorrect or inappropriate actions that could result in component or system unavailability.
Diversity	The use of totally different approaches to achieve roughly the same results (functional diversity) or the use of different types of equipment (equipment diversity) to perform the same function. Equipment diversity can be considered in terms of construction, physical characteristics, applying this applying this concept. Diversity is a tactic that specifically addresses CCFs.

5 SURVEY AND ANALYSIS

The data collection shown below demonstrates the actual scenario and reflection from leader's experience in nuclear automation project. The survey identified leadership and human factors as a key factor or are responsible for managing the risk associated for accidents /incidents/failure in nuclear automation project.

Figure 12 (Haskins et al,2004) gives a clear understanding and a graphical representation for the real impact of the cost on the project to correct an error in a requirement during different project life cycle stages. The cost along the life cycle increases exponentially which becomes a major factor for project delay subsequently to project failure.

-The cost of fixing a requirements error discovered during the requirements phase is defined to be 1 unit, the cost to fix that error if found during the design phase increases to 3–8 units; at the manufacturing/build phase, the cost to fix the error is 7–16 units; at the integration and test phase, the cost to fix the error becomes 21–78 units; and at the operations phase, the cost to fix the requirements error ranged from 29 units to more than 1500 units.

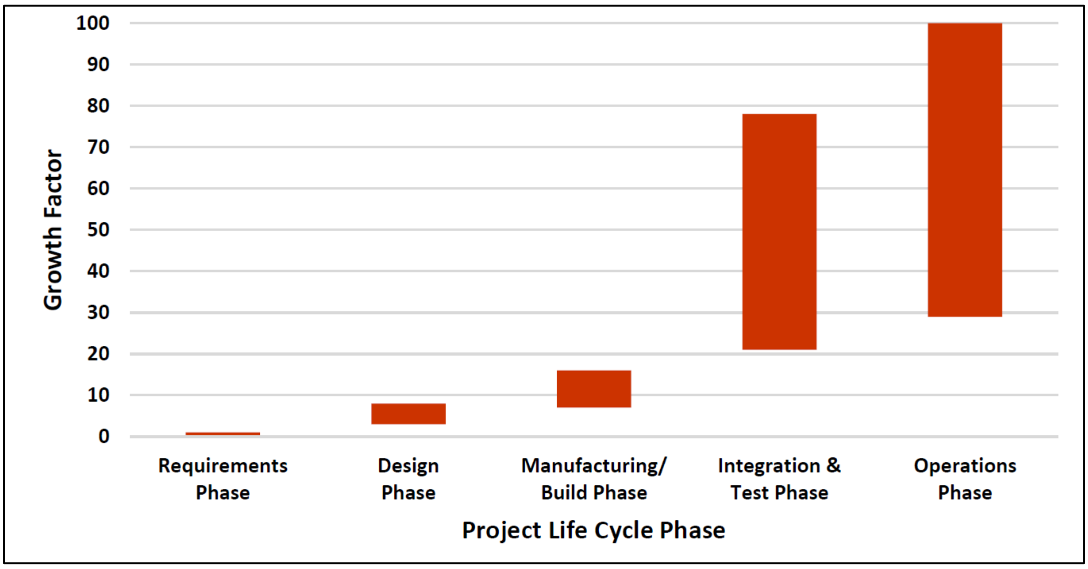


FIGURE 12. Cost of fixing a requirements error along the project life cycle (Derived by the author from Haskins et al. (2004)

5.1 Survey questions and risk factors

Survey conducted with various experts, leaders, and engineers involved in nuclear automation project as mentioned in appendix 1 with online meeting with actual project discussion. The names are not disclosed due to secured information and following the safety standard of safety and security of information system in nuclear project.

Leadership plays an extremely vital role in shaping an organizational culture and behaviours. Therefore, a conscientious assessment of the leaders' mindset, skills, knowledge, and approach is carried out to understand the change, which is essential to the development of a constructive, strong nuclear safety culture.

Survey questions mentioned below are created to do identify the gaps in the nuclear automation project.

5.1.1 Survey question 1

What are main measure and controls kept in consideration when a leader methodically communicates his/her major beliefs?
It has a significant influence when it is communicated to the organisation front based on the recruiting or staffing right skilled and proficient candidate. It has an influence on the organisational work culture if the leader is consistent in communicating the expected needs for common goal and focus of attention.

5.1.2 Survey question 2

How leaders respond to critical situation or incidents and manage organizational crises?
Leaders must be organised to handle unexpected challenges with flexibility, persistence, and a valuable questioning attitude. Experiencing crisis create new leadership quality with that one can create new required norms, procedure and important instructions based on realistic assumptions.

5.1.3 Survey question 3

How leader model the teaching, training, and coaching environment?
From a leadership development perspective, leaders ensure with coaching skills which create opportunity to the managers, supervisors, team member to develop the necessary skills that will allow them to adhere to the desired behaviour and respect the organisation policies, rules, and procedure.

5.1.4 Survey question 4

How leader allocate criteria by which the team member is acknowledged for work and rewarded?
Leaders follow the subsequent major criteria to identify the people to be recognised for contribution. • High reliability within organizations as required for a nuclear power project. • Managing time and resources in accomplishing work and manage the constant challenges in the project.

5.1.5 Risk factors

The risk assessment is divided into following 4 groups or categories to identify the risk associated to the organisation on account of leadership.

- Organisational control and environment risk.
- Organisational strategic risk.
- Organisational operation risk.
- Organisational compliance risk.

The risk details are described in detail for all above mentioned risk.

5.1.6 Risk descriptions

The 4 groups mentioned in the section 5.1.5 are further elaborated and fragmented into factors responsible for the risk.

1. Organisational Control and Environment Risk	
Organizational Structure Risk	Organizational structure defines key areas of responsibility and establishes accountability.
Commitment to Competence Risk	Competence of the employee base reflects the knowledge and skills needed to perform assigned tasks. Management with appropriate amount of care on acquiring and retaining the competent skilled people necessary to achieve the business's goals and objectives.
Assignment of Authority and Responsibility Risk	Organisation assignment of authority and responsibility clearly establishes the degree to which individuals and teams are authorized and encouraged to act to address issues, solve problems and take advantage of presented opportunities. Individual's roles, responsibility, and actions are interrelated and contribute to accomplishment of the company objectives.
People management risk	Team management, handling conflict, managing diversity and integration.
Cultural diversity Management risk	Multicultural environment due to people from international experience and belong to different country, culture etc. Developing an organisational culture from this multi culture environment.
Safety culture and human factor risk	Developing safety culture through awareness and information sharing within organisation and changes occurring during the process.
Human Resource and recruitment risk	Standards appropriately address hiring, orientation, training, evaluating, counselling, promoting, compensation, and remedial actions, driving expected levels of integrity, ethical behaviour, and competence.

2. Organisational Strategic Risk	
Competitor Risk	Business competition due to new participants in the same field of business or engineering threaten the company's competitive position.
Stakeholder Integration Risk	Multiple stakeholder involvement needs a higher level of integration and communication between all stakeholder with open discussion to have a common understanding and conclusion.
Catastrophic Loss Risk	In case of engineering, it is the licensing process which may bring a major disaster threatens the company's ability to sustain and provide essential services along with the operating costs.
Data Exposure Risk	A significant exposure of sensitive data entrusted to the company's care causes the company to publicly disclose security weaknesses or outsider intrusion.
External Data Risk	Interruption to the availability and quality of external data significantly impairs the functionality or value of the company provided services.
Technology Shift Risk	Dramatic shifts or adjustments in emerging technology are not capitalized upon due to the company’s reliance on current patterns and portfolio.
Social and Political Risk	Social or political adverse situation and actions significantly impact and threaten the company's resources and future.
Planning Risk	Project planning define the entire process for manging project, controlling project, and executing the project.
Project lifecycle and time schedule Risk	Risk of not effectively managing the movement of company’s product lines and monitor the development of its industry during the relevant life cycle.
Organisational Reputation Risk	Company market value is the face of the company and create respect in the market for company and its product. The risk that the company sales reduced due to loss of consumers, loss of key resource and employees, impacting company’s reputation in the marketplace.

3. Organisational Operational Risk	
Customer Satisfaction Risk.	Company processes when do not meet consistently or exceed customer expectations potentially create risk by impacting future growth prospects and earnings potential for company.
Contractual Commitment Risk	Lack of relevant and reliable information about existing contract commitments may prevent decision makers from making decisions about potential progressive commitments and may result in decisions which is not in favour of the company.
Resource Allocation Risk.	Company resource allocation process does not establish and sustain competitive advantage or maximize returns.
Employee Satisfaction Risk	Company not focusing on aspects of a conducive work environment necessary to ensure continued employee satisfaction.
Process Efficiency, Effectiveness, and Performance Risk	Inefficient or ineffective or poorly designed operations and unnecessarily slow processes put company's ability to achieve business objectives at risk.
Budget and Planning Risk.	The budget is directly linked to planning as the project schedule is impacted than it has direct impact on the incremental of cost.
Communications Risk.	Improper information & communication channels which create a risk of misunderstanding due to inconsistent messages from responsible authority and do not effectively convey information as intended.

4. Organisational Compliance Risk	
Legal and Regulatory Risk.	The risk of changes in laws, guideline, regulations or litigation claims and assessments result in a reduction to the company's ability to conduct the business efficiently.
Regulatory Compliance Risk.	Nonconformance with current laws and regulations exposes the company to limited sanctions, fines, and penalties which threatens the company's reputation, business opportunities, and expansion potential.
Non standardisation Risk	The standards which are norms to be followed to keep the quality and reliability of the product. However, non-standard design is a big risk for a nuclear power project
Taxation Risk	The risk that the company is not in compliance with all tax regulations and requirements. Adverse tax consequences that could create risk which could be avoided unless properly reviewed and structured.

5.1.7 Risk analysis

Based on study for the nuclear automation project, 29 risk parameters as shown in the table 9 are identified and utilised for the risk assessment. This is to bring leadership focus on major risks associated and to mitigate the risk within the organisation to minimise the impact with respect to time, cost, and resource.

Risk is part of project in every phase of lifecycle, however a cautious proactive approach to understand the risk by leaders bring the project to achieve success in the different phases.

TABLE 9. Survey parameters for risk assessment (Garvey. P. R, 2008).

	Risk assessment matrix			
	RISK description	Likely hood of occurrence	Impact	Risk Priority Number (RPN)
	Organisational control and environment risk			
R1	Organizational structure risk	3	3	9
R2	Commitment to competence risk	2	3	6
R3	Assignment of authority and responsibility risk	2	4	8
R4	People management risk	2	4	8
R5	Cultural diversity management risk	2	4	8
R6	Safety culture and human factor risk	2	5	10
R7	Human resource and recruitment risk	3	4	**12**
	Organisational strategic risk			
R8	Competitor risk	3	3	9
R9	Stakeholder integration risk	3	5	**15**
R10	Catastrophic loss risk	2	2	4
R11	Data exposure risk	1	4	4
R12	External data risk	1	3	3
R13	Technology shift risk	3	4	**12**
R14	Social and political risk	2	2	4
R15	Planning risk	3	3	9
R16	Project lifecycle and time schedule risk	3	4	**12**
R17	Organisational reputation risk	2	4	8
R18	Design change management risk	4	4	**16**
	Organisational operational risk			
R19	Customer satisfaction risk.	2	4	8
R20	Contractual commitment risk	4	4	**16**
R21	Resource allocation risk.	2	3	6
R22	Employee satisfaction risk	3	4	**12**
R23	Process efficiency, effectiveness, performance risk	3	3	9
R24	Budget and planning risk.	2	4	8
R25	Communications risk.	3	3	9
	Organisational compliance risk			
R26	Legal and regulatory risk.	2	5	10
R27	Regulatory compliance risk.	3	5	**15**
R28	Non standardisation risk	2	4	8
R29	Taxation risk	1	5	5

The data collected from the survey is further elaborated as a chart representation for identifying the major cause within these parameters.

Organisational control and environment risk chart

Organisational strategic risk chart

Organisational operational risk chart

Organisational compliance risk chart

5.1.8 Risk identified and data analysis

The sampling of 29 parameters in 4 categories, survey of 13 leaders mentioned in the appendix 1 of different field in nuclear power project (NPP) carried out to identify the critical and major risk within a project. As per appendix 5 (Garvey. P. R, 2008).

Risk Matrix from the survey, discussion, and interview for nuclear power project (NPP) (Garvey. P. R, 2008).

Probability of occurrence	Almost certain					
	Probable				R18, R20	
	Possible			R1, R23, R25	R7, R13, R16, R22	R9, R27
	Improbable		R10, R14	R2, R8, R15, R21	R3, R4, R5, R17, R19, R24, R28	R6, R26
	Almost impossible			R12	R11	R29
		Insignificant	Less insignificant	Significant	Major	Critical
	Impact					

Observation 1

The survey analysis identified the 4 critical risk as marked in red in the above-mentioned risk matrix. These risks are key points to be considered by the leaders to construct a safe and successful nuclear power project.

- Contractual commitment risk (R20)
  84.6% leaders and expert think that it is true as per survey.
- Design change management risk (R18)
  76.9% leaders and expert think that it is true as per survey.
- Stakeholder Integration risk (R9)
  69.2% leaders and expert think that it is true as per survey.
- Regulatory compliance risk (R27)
  69.2% leaders and expert think that it is true as per survey.

Observation 2

The survey analysis identified the following major risk some with higher impact and some with higher occurrence.

- Human Resource and recruitment risk (R7)
  92.3% leaders and expert think that it is true as per survey.
- Employee satisfaction risk (R22)
  84.6% leaders and expert think that it is true as per survey.
- Project lifecycle and time schedule risk (R16)
  76.9% leaders and expert think that it is true as per survey.
- Technology shift risk (R13)
  61.5% leaders and expert think that it is true as per survey.
- Assignment of Authority and Responsibility Risk (R3)
  76.9% leaders and expert think that it is true as per survey.
- People management risk (R4)
  84.6% leaders and expert think that it is true as per survey.
- Cultural diversity Management risk (R5)
  53.8% leaders and expert think that it is true as per survey.
- Organisational Reputation Risk (R17)
  69.2% leaders and expert think that it is true as per survey.
- Customer Satisfaction Risk (R19)
  76.9% leaders and expert think that it is true as per survey.
- Budget and Planning Risk. (R24)
  100% leaders and expert think that it is true as per survey.
- Non standardisation Risk (R28)
  61.5% leaders and expert think that it is true as per survey.

5.1.9 Risk analysis comparison with survey of other industries

Comparison to other industry like information technology and food business, the similar survey done with 7 leader and expert with 11 parameters to understand the risk associated with their organisation. As per appendix 5 and measured risk with calculated RPN is shown in table 10.

TABLE 10. Risk assessment matrix (Garvey. P. R, 2008).

Risk assessment matrix - IT and food business				
	RISK description	Likely hood of occurrence	Impact on occurrence	Risk Priority Number (RPN)
R1	Commitment to competence risk	2	3	6
R2	People management risk	1	3	3
R3	Market and competitor risk	3	3	9
R4	Planning risk	3	4	**12**
R5	Organisational reputation risk	2	4	8
R6	Customer satisfaction risk.	3	4	**12**
R7	Contractual commitment risk	3	4	**12**
R8	Employee satisfaction risk	2	3	6
R9	Budget and planning risk.	2	4	8
R10	Regulatory compliance risk.	2	5	10
R11	Taxation risk	2	5	10

The risk was calculated, and a chart representation was prepared to identify the critical risk associated with these organisations.

The survey analysis identified the 3 critical risk.

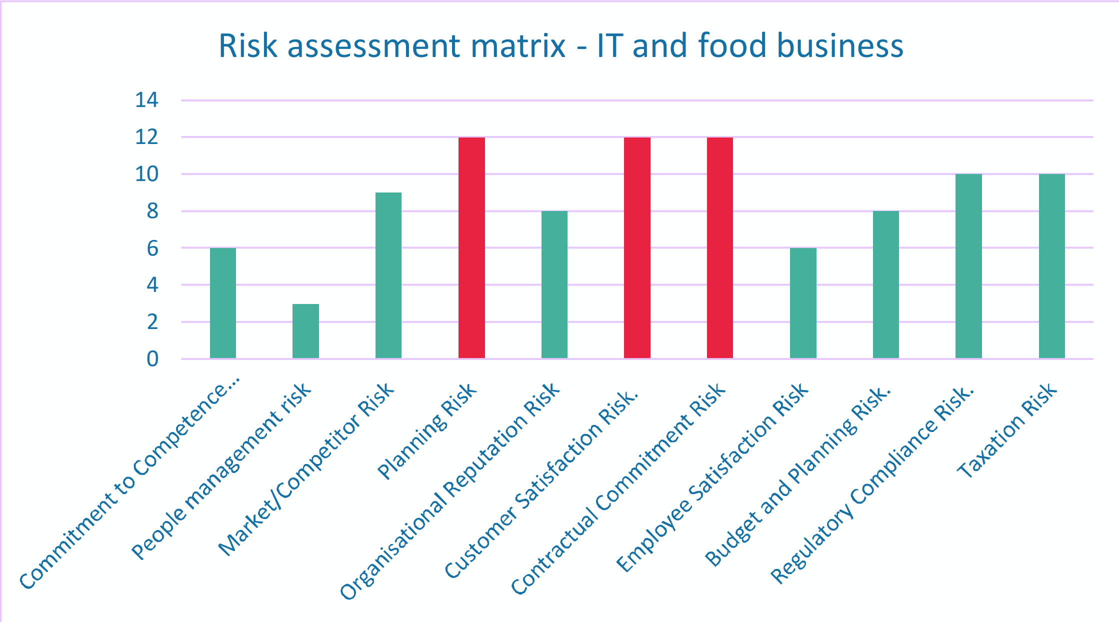
- Planning Risk (R4)

  69.2% leaders and expert think that it is true as per survey.
- Customer satisfaction risk (R6)

  76.9% leaders and expert think that it is true as per survey.
- Contractual commitment risk (R7)

  84.6% leaders and expert think that it is true as per survey.

Risk matrix chart of IT and food business



Risk matrix from survey of IT and food business (Garvey. P. R, 2008).

Probability of occurrence						
	Almost certain					
	Probable					
	Possible			R3	R4, R6, R7	
	Improbable			R1, R8	R5, R9	R10, R11
	Almost impossible			R2		
		Insignificant	Less insignificant	Significant	Major	Critical
	Impact					

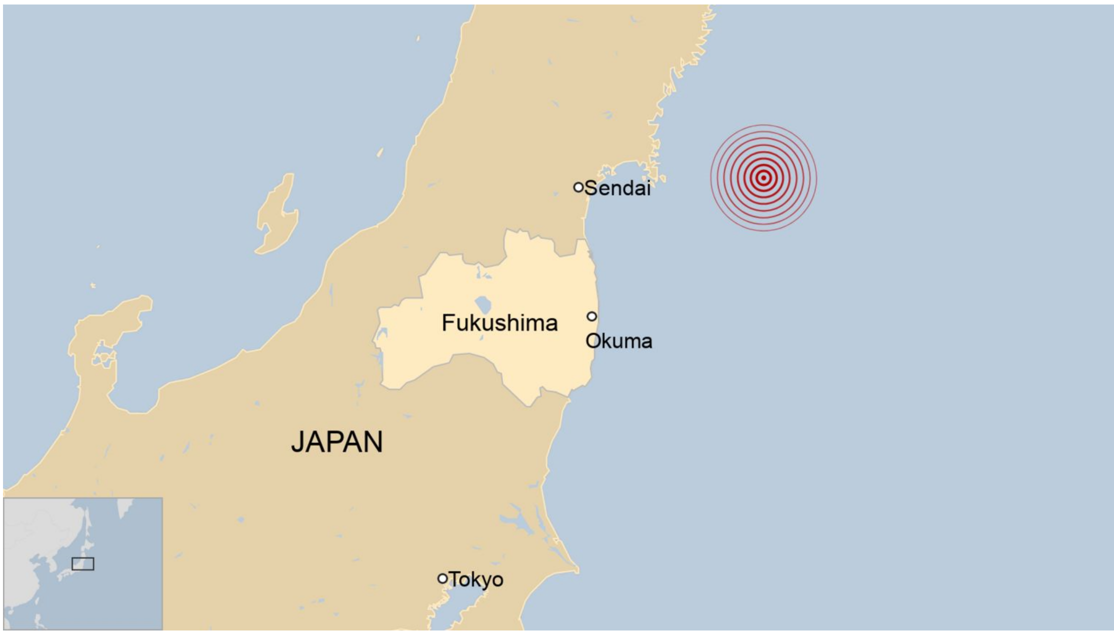
This is clear indication that the risk associated in different organisation depends on the type of business. However, the contractual commitment risk is observed common in all the project as the liability and obligation between client and supplier defines the scope and actual cost implication based on time and delivery. The conflict in contracts is sometime observed during execution of the project and sometimes amendment in contract is required during project execution. Therefore, the contractual inputs or clarification by leaders should discuss with different departments like, legal, quality, procurement, planning & scheduling, document management team, technical etc. This will lead to minimise the contractual liabilities.

6 LEARNING FROM OTHER NUCLEAR PROJECTS

6.1 Fukushima nuclear power project disaster

On 11 March 2011 at 14:46 hours local time the earthquake strikes the east Sendai city of Japan which was approximately 97KM far from the nuclear power plant (Tsirida. T, 2013).

Normally the safety system of nuclear power plant is designed to trip and shut down the reactor however, the residual heat removal is a critical process during shut down. To run the coolant pump around the core during power loss is supported by emergency diesel engine. But the sea water waves which was over a height approx. 14 meters as marked near site in picture 2 that entered plant area and flooded the emergency diesel engine. Soon followed with chemical explosions exploded as shown in picture 3 and the Fukushima disaster occurred.



PICTURE 2. Fukushima nuclear power plant site during explosion (@ bbc.com).

PICTURE 3. Fukushima nuclear power plant site during explosion (@ bbc.com).
(The damage led to nuclear meltdowns and several hydrogen explosions.)

The Fukushima disaster is big learning for handling big nuclear projects, there design and operation keeping importance of safety. It has increased scrutiny of the safety and security systems of nuclear power plants. And these are now more strict mandates as per regulatory bodies and environmental activists around the world.

Responding to the different concerns about the safety and feasibility of the nuclear power plants, post-Fukushima, it was identified the need for building future leaders within the nuclear power plants based on leading projects with respect to safety concern, risk associated, and human factor involved in the various stages of the nuclear project development. To accomplish this need, it requires a significant investment of time, energy, and resources.

6.2 Chernobyl nuclear power project disaster

On 26 April 1986 at 01:24 hours, reactor 4 experiment start for investigating the reactor safety in the event of failure condition of main power supply. Immediately after the experiment started within a minute of time the explosion blew the top lid of the reactor building causing in releasing of radioactive material in environment. It was world worst accident happened in the history of nuclear power plant which threatened the entire humankind forever (Blakemore. E, 2019) (Gray. R, 2019).

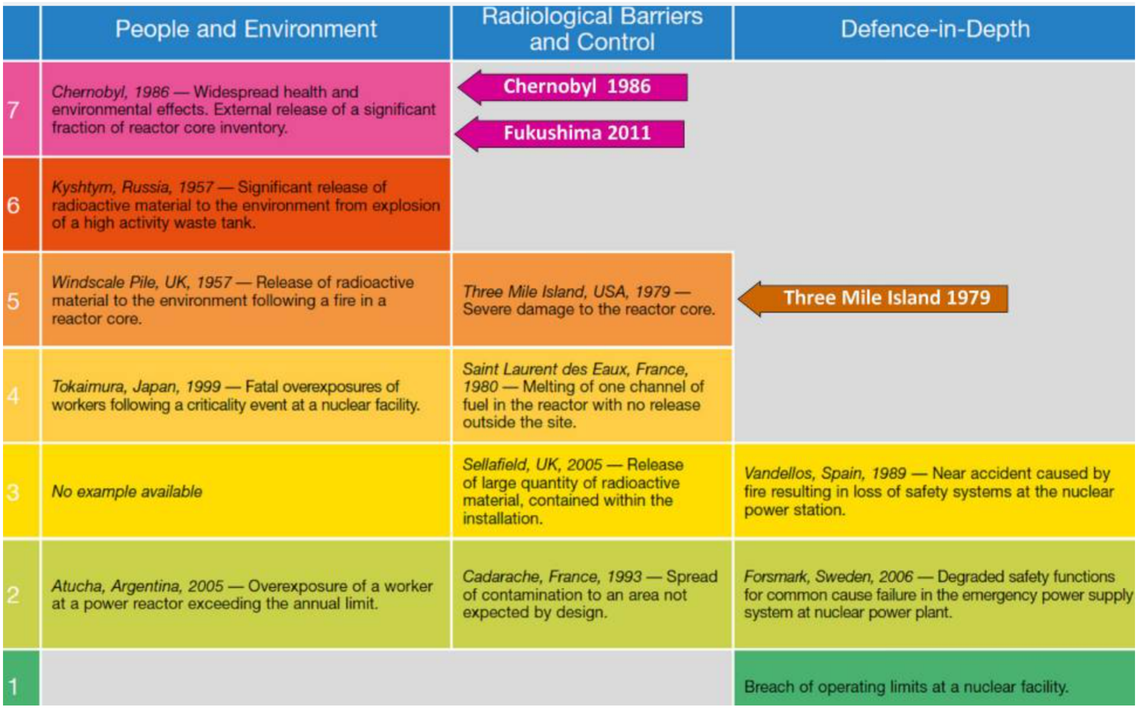
PICTURE 4. Chernobyl power plant site after disaster (@bbc.com).

With the consequence of the disaster the initial observation found as shown in picture 4. Following disaster measured mentioned below to realise the impact of a nuclear plan failure consequence.

- Thirty-one engineers, firemen and emergency clean-up workers recognised within first 3 months dying after the explosion. And over 36,000 men died because of the disaster.
- Some of those living closest to the power plant received internal radiation doses in their thyroid glands which is up to 37,000 times more than dose of a chest x-ray.
- Over 100,000 people were evacuated from the area around Chernobyl nuclear power plant within a month.
- Death rates from these brave individuals raised from 3.5 to 17.5 deaths per 1,000 people between 1988 and 2012. Disability among the liquidators has also raised. In 1988 68% of them were regarded healthy, while 26 years later just 5.5% were still healthy. Analysis says 63% were reported to be suffering from cardiovascular and circulatory diseases while 13% had problems with their nervous systems.

6.3 Other nuclear power project severe accidents impact

Picture 5 represent radiological impact due to other nuclear sever accidents as per (Lars. H, 2013) described below. In 1979 the another severs nuclear accident occur was “Three Mile Island” other than Chernobyl and Fukushima. Picture 5 shows the radiolocation consequences in other nuclear plant happened due to incidents.



PICTURE 5. Events at nuclear facilities, graded as per International Nuclear. Event Scale (INES). (*Source*, IAEA).

6.4 Learning from the disasters

The nuclear power project is a great responsibility of leaders leading different projects considering humankind at the topmost priority.

The focus of the thesis is also to improve leadership thought process, collectively increasing human and plant performance. Developing new leaders with much higher understanding of the responsibility, leaders must understand and support the need to develop the leadership management and technical skills of all leaders to perform their assigned tasks.

6.5 Analysing the data and inputs

The following major take away analysed for leaders to follow from Fukushima disaster.

- Application management system for all usage of situation of emergencies and disturbance.
- Procedure for enabling quicker intervention, like decision making hierarchy and efficient way of conveying the information in emergency.
- Developing a higher level of safety culture, with training need for providing awareness for the nuclear and radiation safety requirements.
- Developing skills for decision making, comprehensive analysis, working professionally and responsibly in a good working environment, open atmosphere, mutual respect, and trust within the organisation.

6.6 Defining the gaps identified

The major gaps identified as a management of human and organisation factors.

- The interaction between human, technology and organisations affects the safety of nuclear power project (NPP).
- Human factor and organisation to be handled in the similar context so as it is for the technical matters.
- Identify the human factor on working performance and the possibility of error.
- Development of personnel’s individual competencies regarding human and organisation factors to mitigate the potential error.
- The organisational safety and quality policies should be clearly communicated to the personnel’s working in nuclear power project (NPP) and to the supplier affecting the nuclear and radiation safety.
- Leaders and management to focus on safety system establishment, implementation, assessment and continue to improve.

7 RISK MITIGATION METHODOLOGY

7.1 Risk mitigation methodology

Once the risks are identified and assessed, it is important to develop a risk mitigation plan shown in figure 13 (Parker. D, Mobey. A, 2004). A plan to reduce the impact of an unexpected event.

The 4 major ways to mitigate risk.

- Risk avoidance
- Risk sharing
- Risk reduction and
- Risk transfer.

However, with the study made during this thesis we will focus on the risk reduction under the role of leadership, as the identified risk cannot be avoided, shared, or transferred.

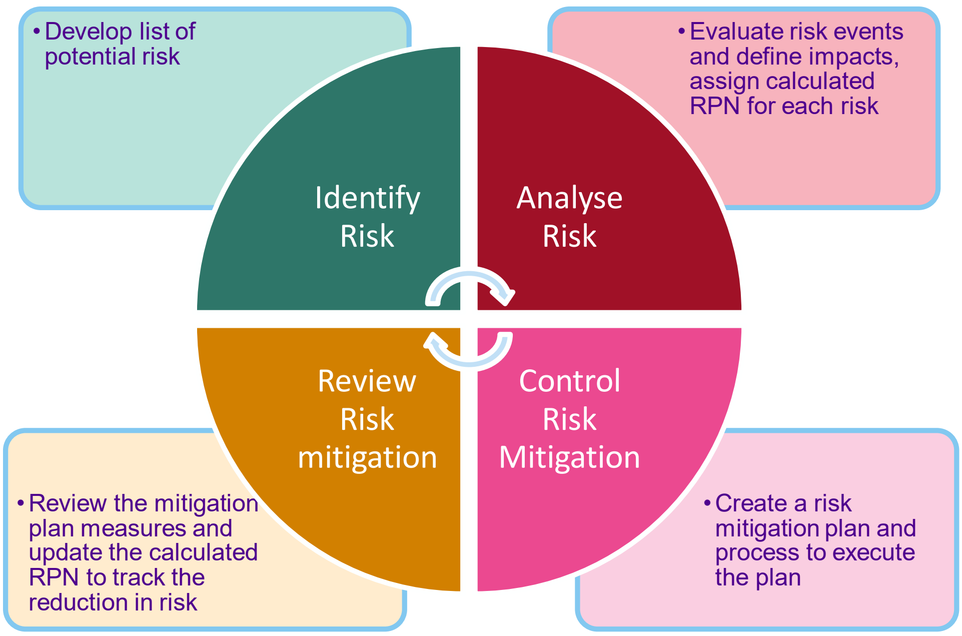


FIGURE 13. Risk Management cycle (Carmen J, 2019, Risk management 101).

Risk management cycle is the process which define the following objectives of

Identifying risk, assessing risk, and reducing risk to an acceptable level. Managing risk by looking forward proactively at how to prevent issues, rather than being only reactive to problems. The risk management method controls the processes, techniques, tools, and responsibilities to be executed. Developing a risk management strategy within the company can capitalize to meet business objectives.

7.2 Risk management plan

Risk management plan as shown in figure 14 (Garvey. P. R, 2008) is very important to mitigate or minimise a risk impact on a project or organisation. The plan clearly defines about risk identification, impact analysis, tracking of the risk identified, prioritisation of risk and then plan to mitigate the risk or minimise the risk probability of occurrence. The complete process is driven by this risk management plan and the leaders associated in the plan.

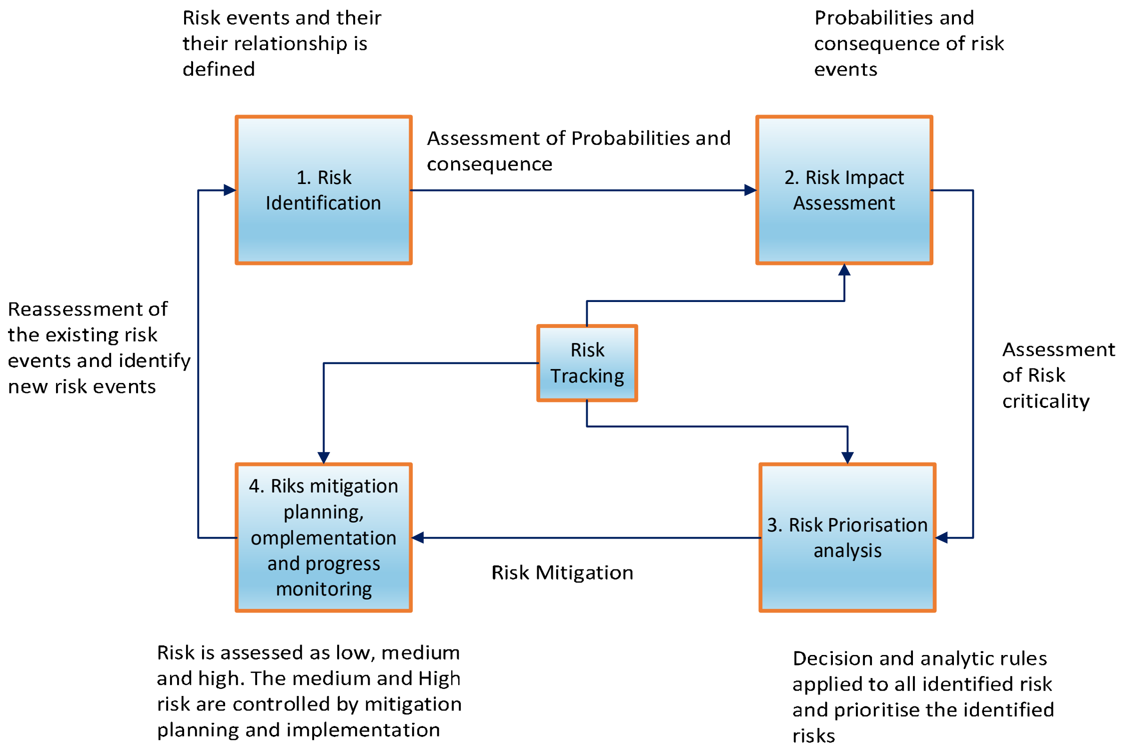


FIGURE 14. Risk management plan (Garvey. P. R, 2008).

7.3 Risk mitigation options

The below mentioned options are effective when followed by implementing a plan and well-defined monitoring or feedback system as shown in figure 14 (Garvey. P. R, 2008).

- To accept the risk, leaders should recognise the presence of a particular risk and make a careful decision to accept the risk without a special effort to control it.
- To avoid the risk, leaders should apply changes to requirements to remove or reduce the risk. This is accomplished by implementing a change in budget, project schedule, or technical requirements.
- To control the risk, leaders implement plan and actions to reduce the impact or occurrence of the risk.
- To transfer the risk, leaders transfer the risk accountability, responsibility, and to another stakeholder who are interested to accept the risk against cost like insurance etc.
- To monitor the risk, leaders should observe the parameters for changes that affect the nature or impact of the risk.

The nuclear automation project or engineering project, the common methods of risk reduction or mitigation with identified risks include the following process which are listed to increasing better understanding of the risk (Kossiakoff. A, Sweet. W. N, 2003).

- Technical and management reviews of the engineering process
- Special oversight of designated component engineering
- Verification or analysis and testing of critical design items
- Testing and result records
- Comply with critical design requirements
- Parallel development

When defining risk mitigation methods, as per the MITRE SE which can benefit the leaders to assess the performance, project planning & scheduling, and cost impacts of due to mitigation planning. Like parallel development as per MITRE SEs which can determine if the cost can be doubled, while time managed and need not to be extended by much (e.g., adding more manpower to meet the timeline or project schedule).

7.4 Risk mitigation plan

The measures for risk mitigation plan are mentioned below.

- Determine the risk manager as a leader. The leader who is responsible for categorising and applying the risk mitigation plan. He or she must have all the necessary inputs, knowledge, resource, and authority to execute the implementation of the plan.
  It is also a risk if the leader is not having enough seriousness for implementing the risk mitigation strategy or plan. The organisation higher authority should address the needs and all support necessary required to the leader.
- Develop a strong mitigation strategy and by implementation reduces the risk impact, the severity and probability and likelihood of occurrence.
- Identify steps and actions required to implement the mitigation strategy. The controlling of the mitigation plan measures is defined in the next section 7.1.5.

7.5 Risk controlling measures

The key measures or the points to control the risk mitigation plan are mentioned below.

- The action to define exit criteria which includes decision, agreement, and outcomes from meeting. Evaluation action, proof, and validation of meeting the criteria. Action to include all relevant stakeholder involved or responsible for the risk mitigation.
- Evaluation of status of each action, to verify and validate that each action is completed successfully.
- Re-evaluate the risk for its risk priority number (RPN) calculated from the probability and impact, to ensure the RPN reduced and consequently the actual risk is reduced.

8 CONCLUSION

To conclude, it is realised learning leadership practices and developing competencies has definite advantage to overcome many critical situations and bring solutions. The competence management has broadened the idea of learning while understanding own *skill* set and with *will* acquire the needs.

The key finding for the leaders explained in next few section or chapters.

8.1 Contractual commitment risk

It is observed that 84.6% leaders and expert think that it is true as per survey that contractual obligation, boundary limits and conditions play an important role in the development and execution of the nuclear project before the operating phase is achieved.

Leaders must identify the gaps in contractual conditions agreed between different stakeholders, as it is observed the integration of different scope of work is major cause for the delay in the project.

The leaders should make a task group for analysing the contractual points. The team should be organised with following experts.

- Legal expert
- Procurement expert
- Technical expert
- Quality expert
- Project planner and scheduling expert
- Commissioning expert and
- Operational expert.

This key team members can understand the contract in terms of project life cycle phase and identify the gaps in different interface in life cycle stages or scope of work.

The project team should be trained with all contractual condition so that everyone can easily understand their scope of work and others scope of work.

8.2 Design change management risk

It is observed that 76.9% leaders and expert think that it is true as per survey that the change management plan during design phase which is a part of the quality framework need to be focussed to follow and trace all critical changes or modification made during the design.

The leaders need to identify the impact of the design change on the project as it is a sequential with the life cycle stages of project.

The design modification will bring change in specification and the product design will follow the specification made during the design. If this design change is not tracked, then the final product has higher chance of wrongly built with wrong specification. This has a direct impact on cost and time.

The design team leaders should follow proper change management process for tracking change, following the process with experience during the project design. The team should be well trained by training from well qualified professional to understand the importance of the change management fundamentals, its requirement, and its frame of work.

8.3 Stakeholder integration risk

It is observed that 69.2% leaders and expert think that it is true as per survey that in a project with different stake holders (for example client, supplier and sub supplier etc.), it is important to harmonise the integration between stake holders with respect to documentation transaction, communication channel, common understanding of project requirements, roles and responsibilities, understanding the deliverables and as mentioned in the section 8.1.1 contractual obligation align with integration or interface of scope of work of different stakeholders. This risk has a direct impact on the project schedule, loss of time, cost, and wrong design.

The team leaders of different stakeholder need to understand the boundary limit of their scope of work and the interface between these boundary limits for various input and output requirements. The leader should make an integration team focused on these interfaces and try to align the roles and responsibilities of different stakeholder within these interfaces to avoid conflict and confusion for design and execution of the project.

8.4 Regulatory compliance risk

It is observed that 69.2% leaders and expert think that it is true as per survey that the regulatory compliance which are mandatory for the requirement specified for the design or during all lifecycle is intended to make the safe and reliable nuclear project.

The regulatory compliance should be known to all people working in the project at least within the scope of their own area of task. This can be achieved through training by a well-qualified professional or from consulting organisation who has these knowledges of regulatory compliances.

The leader should arrange such training, which should be mandatory for everyone followed with an examination to ensure the learning of the people trained is achieved as per the intend.

After all the analysis and conclusion with risk assessment it is well identified that a good leader and good team can work efficiently when they are well trained and guided with correct procedure. They should be prepared with right knowledge of the subject or requirement. Therefore, training, and good procedure are the key areas which can mitigate all these risks which were identified during the survey for a complex nuclear automation project and not limited to only automation only but the entire nuclear power project. To understand it conceptually, it is elaborated in the section 8.2 with a derived matrix shown in figure 15.

8.5 Conceptual derived risk matrix

As a conclusion a derived risk matrix is developed based on two parameters *procedures and training.* It is recommended to establish procedure and training module for different process to work efficiently & effectively. The risk matrix defines explicitly four risk zones which are defined in figure 15. The procedure is important to explain the steps and instructions to complete a process. And to understand the objective of the process training is important to explain the intend of the procedure. The risk matrix is based on inputs from appendix 5 (Garvey. P. R, 2008), where it is clearly defined the probability of occurrence of a risk event and represent the consequence category. The method is simple but very effective tool to visualise a risk and can be mitigated with a corrective decision.

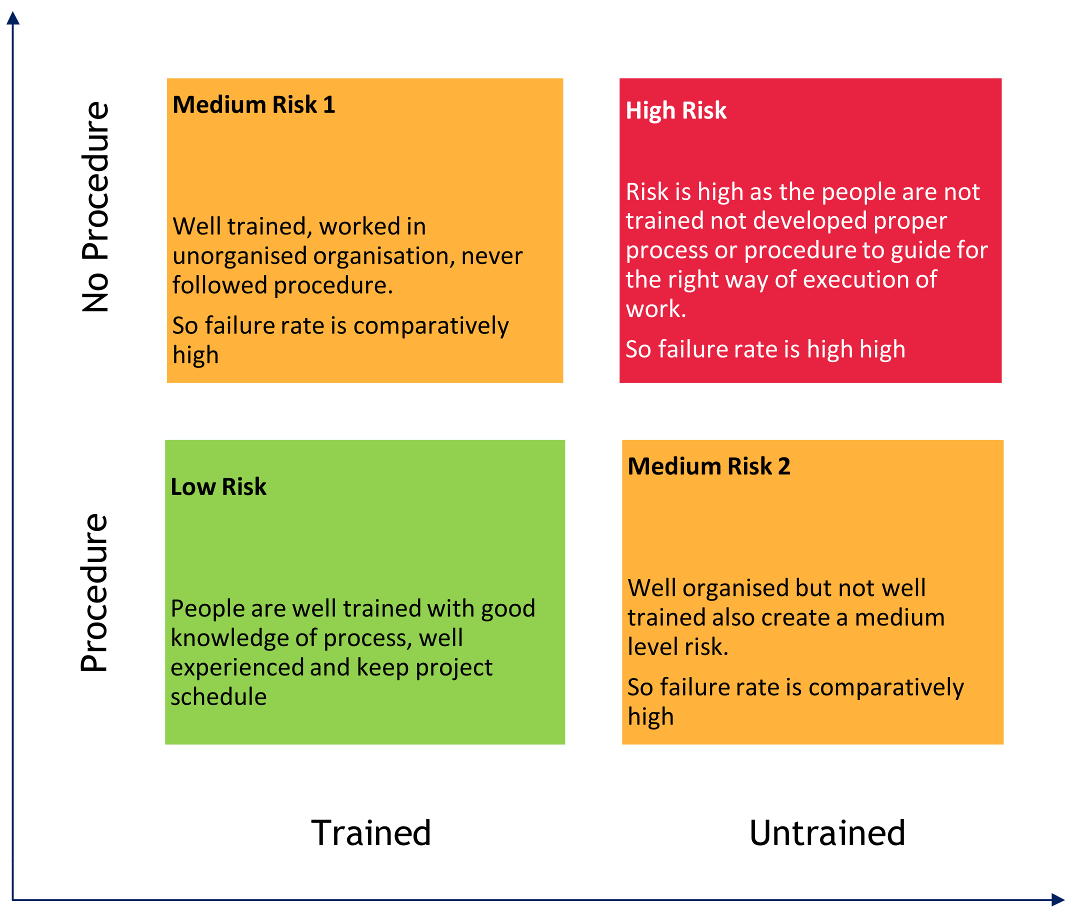


FIGURE 15. Derive risk matrix identified from conclusion.

The leader can use this risk matrix to identify the zone of risk and can define the requirement based on the following zone description.

The risk matrix in figure 15 is formalised in 4 zones or levels, low risk, medium risk 1, medium risk 2, and high risk. The zone evaluates the risk based on its likelihood of occurrence and accordingly the extent of the impact can be analysed. Therefore, the leaders can easily categorise the need of training and developing different procedure for people working in nuclear project.

ZONE	High Risk
	The leader can identify this zone with following observations made on the team members. • No proper evaluation and training organised. • No clarity of project scope, objective, and requirement. • No clarity of procedure and processes flow. • No clarity of roles and responsibility.
ZONE	Medium Risk 1
	The leader can identify this zone with the following observations made on the team members. • No clarity of procedure and processes flow. • No clarity of project scope, objective, and requirement • Team has a proper training and evaluation done.
ZONE	Medium Risk 2
	• The leaders can identify this zone with the following observations made on team members. • No proper evaluation and training organised. • No clarity of roles and responsibility • Team understand project process flow and procedure.
ZONE	Low Risk
	The leaders can identify this zone with the following observations made on the team members. • Team has a proper training and evaluation done. • Team has clarity of roles and responsibility. • Team has clarity of project scope, objective, and requirement. • Team understand project process flow and procedure.

9 RECOMMENDATION

The leader possesses a successful leadership which primarily depends on self-leadership as described in chapter 2 and how clearly understand the need of the people those are leading. The leader must identify the right people or develop the people to become right with a framework of good *process & procedure* along with *training*.

The human behaviour of team and people are equally important aspect of managing people. The cultural diversity is also a strength and risk as well. So, the leader needs to focus on the opportunity arises due to diversity within the team.

The leader is always focused on the strength and weakness of his team members so that he can coach the people as per individual requirement to develop as an important resource for the project. The project objectives are aligned only when the individual people are aligned within self and intended to be an individual leader within.

The leader needs to focus on the work environment, which is important for successful project, to bring new ideas, to interact with open culture, to accept the people weakness to enhance the dignity and confidence of the team. This is directly reflecting on the project execution environment.

Project process and internal procedure play an important role in the development of the team and people understanding the project objectives. As concluded in the conclusion for defining the different project procedure which are important to be followed as elaborated in the section 9.1. And defining training as elaborated in the section 9.2 for people if needed to harmonise understanding of the project requirement.

9.1 Recommendation for defining procedure

The internal and project procedure are developed to guide people and project to harmonise, trace and integration of project stake holders.

Project base procedure

As per the quality and project management framework (ISO 10006, ISO 10007, 2003) the following procedure identified.

- Change management procedure
- Document management procedure
- Communication management procedure
- Project management, planning, and schedule
- Risk management procedure
- Quality management procedure
- Project integration procedure.

9.2 Recommendation for defining training

The scientific analysis (Edmonds. J, Mitchell. J, 2016) defines training are the means of development by which an individual or a team competence is enhanced. Safety critical work such as nuclear power project is a responsible job. It should comprise of appropriate training and focus on development.

This training means may be of different forms, like a classroom-based training or simulation or online etc. However, the present thinking in learning and development uses the concept of the 100% divided into ratio of "70:20:10" model.

This means 70% of learning & development comes from performing job tasks and encountering problems that allow experimentation, previous experience, practice, and improving continuous skill set; 20% arises from social learning and coaching; and the 10% of development is achieved by classroom and online learning.

Training need assessment is done in 5 stages. The training need is to contribute to development of the individual or team competence (Edmonds. J, Mitchell. J, 2016).

- Scope of training defined for the new system, new equipment, new method.

- Operational task analysis to define specific role and responsibilities.
- Training gap analysis is performed to identify the gap between existing skills knowledge to the required skills & knowledge.
- Training options analysis is done for training effectiveness, cost involved, and risk involved in training process.
- Training plan includes the package of training, training schedule and assessment or feedback.

Hence the thesis analysis is also agreeing the scientific approach. The analysis done through this thesis define that the nuclear automation project to bring training department in application to organise training with various topics which are identified for the development of the people and understand the project with respect to project requirement.

Project base Trainings

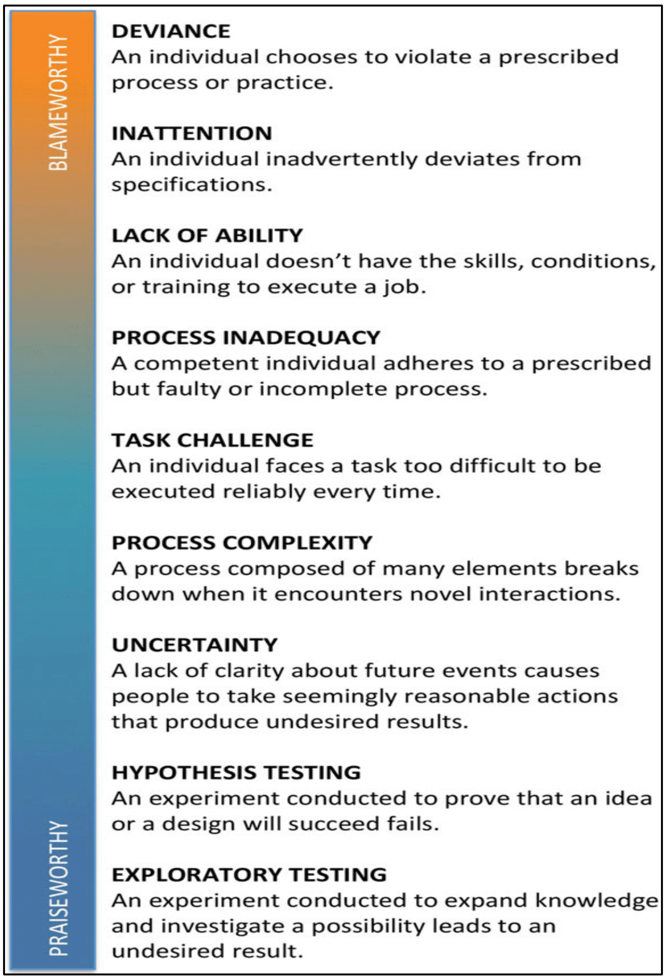
The following list of project-based training suggested for the nuclear automation project to be conducted. As it is defined in the IAEA integrated nuclear infrastructure training report by interregional technical cooperation project INT 2018 (source IAEA), to support knowledge, decision making, and building capacities.

- Training on contract, EPC requirement, and its importance.
- Training on regulatory requirement and compliance assessment methodology.
- Training on organisational values and beliefs with a proper understanding of the objectives.
- Training on human behaviour and human potentials in working environment and the impact.
- Training on understanding roles and responsibility for individual and for project.
- Training on organisational integration between different stakeholders.
- Training on safety aspects of plant and people in working environment and project.
- Training on communication management like assertive communication etc.

10 DISCUSSION

The leader, leadership and risk are a wide subject with continuous learning, analysis with opportunities for developing various process and procedure. The evaluation in this thesis is not limited to what I have analysed however the discussion is open to other important factors which need to be considered and addressed. The broader aspect of failure is learning and experience. The learning from the failure is one of the attribute which leader need to possess for developing self and team. Believing in self is a big factor which allow to accept the up and down in personal and professional front.

As shown in picture 6 (Edmondson. A. C, 2011), the spectrum of failure which define the reasons for the failure. Most of the people think failure is bad, but that is a consequence of various risk which were neglected during the process. So, majorly in other words -*learning from failures is to improve future performance*. The topic is still open for many other discussion points.



PICTURE 6. Spectrum of failure (Edmondson. A. C, 2011).

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APPENDICES

Appendix 1. Survey of different leaders and experts

- List of survey people from nuclear power project

Survey No	Name	Role
1	Leader AA	Director of branch
2	Leader BB	Manager quality management
3	Leader CC	Manager technological
4	Leader DD	Manager technological (Architecture)
5	Leader EE	Manager technological
6	Leader FF	Manager V&V
7	Expert GG	V&V Team
8	Engineer HH	Engineer supporting technological
9	Engineer II	Engineer supporting technological
10	Engineer JJ	Design Engineering
11	Engineer KK	Design Engineering
12	Engineer LL	Design Engineering
13	Expert MM	Automation Technology

- List of survey people for IT and Restaurant business to do risk comparison

Survey No	Name	Role
1	Expert AA	IT Head
2	Expert BB	IT specialist
3	Expert CC	IT specialist
4	Entrepreneur DD	Restaurant business
5	Entrepreneur EE	Restaurant business
6	Manager FF	Restaurant business
7	Supplier GG	Vendor

The survey conducted with questionnaire related to leadership requirement. The names for the survey are not mentioned intentionally to keep the individual confidentiality intact.

Appendix 2. Quality plan contents from STUK guidelines YVLA.3

A quality plan complementing the management system and pertaining to a delivery shall specify, to the appropriate extent, the following information.

- responsibilities and obligations of the supplier as well as interfaces with other suppliers or organisations contributing to the delivery in question
- standards and guidelines to be complied with in the delivery
- supply organisation and assurance of sufficient resources and competence
- potential division or phasing of delivery
- initial data of the delivery and the resulting documents and records
- reviews relating to delivery and its division or phasing, including the content of the reviews, performing party, acceptance criteria, and the responsibilities and decision-making procedures to be followed
- procedures for subcontractor supervision
- procedures for the management of the technical configuration and modifications
- delivery-specific processes of the supplier’s management system and their potential delivery-specific additions
- consideration of safety significance in accordance with subsection 3.5 of Guide YVL A.3
- ensuring a good safety culture in the delivery
- management of human and organisational factors in the delivery
- updating procedures for the quality plan.

Appendix 3. Safety culture from STUK guidelines YVLA.3

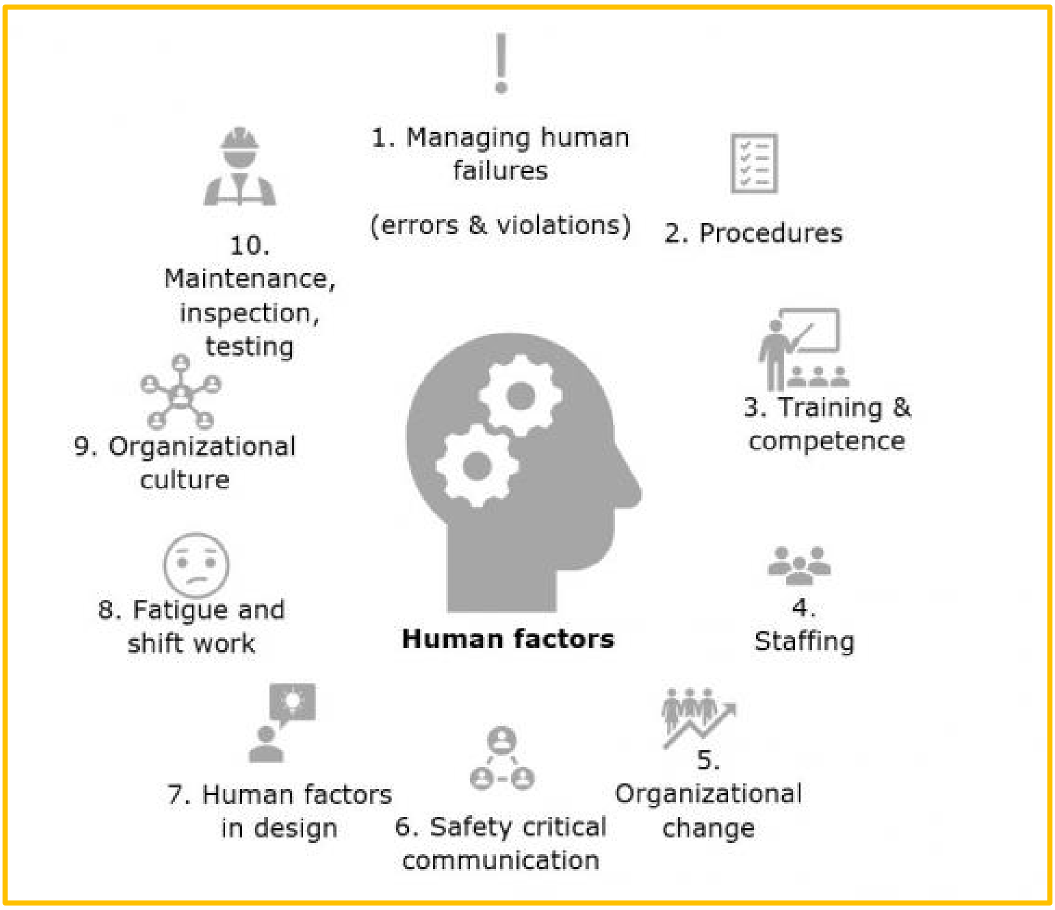
The organisation shall have a good safety culture.

- Nuclear and radiation safety take priority in decision-making.
- The safety significance of issues is considered holistically.
- Work activities are conducted in a professional manner and individuals take responsibility.
- Working conditions are well-organised.
- Mutual respect and trust permeate the organisation.
- The atmosphere is open, blame-free, and vigilant to identify, report, investigate and resolve factors endangering safety.
- The management demonstrates the importance of safety and their commitment to its continuous improvement in the work practices. The management system shall support the development of a good safety culture.
- management of human and organisational factors in the delivery
- updating procedures for the quality plan.

Appendix 4. Mind map, human factor performance management

(Edmonds. J, Mitchell. J, 2016).

- Human factor performance is mainly influenced under following circumstance and has larger impact or effect on the project and to individual.
- Therefore, a mind map is defined to explain the various factors responsible for human performance management.



PICTURE 1. Top 10 human factor aspects in high-hazard industries

Risk Matrix

A risk matrix (Garvey. P. R, 2008) is a matrix that is used for identification of events which are counted as risk based on this risk assessment. This is also used to define the level of risk with category of probability or likelihood for the category of consequence severity or its occurrence.

This is a simple mechanism to increase visibility of risks and assist management decision making.

Probability

Very Likely	Acceptable Risk (medium – 2)	Unacceptable Risk (high – 3)	Unacceptable Risk (extreme – 5)
Likely	Acceptable Risk (low – 1)	Acceptable Risk (medium – 2)	Unacceptable Risk (high – 3)
Unlikely	Acceptable Risk (low – 1)	Acceptable Risk (low – 1)	Acceptable Risk (medium – 2)
Ocurrence / Impact	Low	Moderate	High

Probability x Impact = Risk

Impact (how serious is the risk?)

PICTURE 1. Top 10 human factor aspects in high-hazard industries

What is a risk matrix?

A risk matrix (also called a risk diagram) visualizes risks in a diagram. In the diagram, the risks are divided depending on their likelihood and their effects or the extent of damage, so that the worst-case scenario can be determined briefly.

In this sense, the risk matrix should be a result of the risk analysis and risk evaluation and is therefore an important component of your project and risk management.

Creating a risk matrix

To create a risk matrix or a risk diagram, the probability of occurrence and the extent of the damage must be evaluated. Then the individual risks are entered into a coordinate system according to these values.

<u>Evaluation of the likelihood of occurrence</u>

There are five levels of entering the likelihood of occurrence. These levels can be expressed in percentages or in semantic concepts. For example,

0-20%, 21-40%, 41-60%, 61-80% and 81-100%

impossible, unlikely, possible, likely, and highly likely.

The criteria for the level of likelihood where a risk is situated must be defined precisely.

<u>Evaluation of the extent of damages</u>

In the same way, the extent of damages can be formulated in five levels, for example, low, middle, high, very high and critical.

Of course, here each level of a damage extent must be described exactly to allocate the corresponding risks.

Advantages of the risk matrix

- Identifies the project risks.
- Creates and presents the risk situation with minimal effort.
- Presents the risk situation visually and comprehensively.
- Presents the risk situation simply for everyone because no prior knowledge is required to understand it.
- Assesses the efficiency of risk measures.