To investigate the effectiveness of functional safety planning, verification, validation and competence throughout the entire process safety lifecycle.

Case study: Tata Steel, Port Talbot works.

MSc Property and Facilities Management

MSc Dissertation (ACFA7003)

Paul Boxer (0250199)

Copyright

Author's Declaration

I declare that the work in this dissertation was carried out in accordance with the regulations of UWTSD. The work is original except where indicated by special references in the text and no part of the dissertation has been submitted for any other degree.

Any views expressed in the dissertation are those of the author and in no way represent those of the UWTSD.

The dissertation has not been presented to any other University for examination either in the United Kingdom or overseas.

I hereby give permission for my work, if accepted, to be available for photocopying and inter-library loan, and for the title and summary to be made available to outside organisations.

Signed: ……….Paul Boxer………..………….

Date: ………20/03/2024………………….

Acknowledgements

This dissertation is dedicated to the memory of loved ones lost during this academic period may you all rest in peace, you'll never be forgotten.

To my partner, thank you for your patience and understanding giving me the time to dedicate to this research; providing the moral support and encouragement to continue when things haven't gone to plan and just being there.

To my children, thank you, you have all experienced major milestones in your lives and I'm so proud of you. You are the reason I keep pushing myself, to show the importance of education and that the ability to learn does not stop once you finish school. You are all capable of realizing your dreams.

Finally, to my friends and colleagues, thank you for offering support and words of encouragement, this, as always mean so much.

Table of contents

Table of figures 1
Table of tables 2
List of acronyms 3
1 Background 5
1.1 Process safety issues 5
1.2 Process safety 7
1.3 DSEAR 9
1.4 Relevant standards - IEC 61508 and IEC 61511 9
1.5 Case study 10
2 Aim & objectives 14
2.1 Aim 14
2.2 Objectives 14
3 Literature review 15
3.1 Functional safety legislation 15
3.2 Functional safety planning in industry 16
3.3 Demonstrating competency, validation, and verification. 17
3.4 Use of templates or checklists as a base for planning 22
4 Methodology 24
5 Results and analysis 26
5.1 Questionnaire analysis 26
5.1.1 General data 26
5.1.2 Question 1 32
5.1.3 Question 2 33
5.1.4 Question 3 34
5.1.5 Question 4 37
5.1.6 Question 5a 40
5.1.7 Question 5b 42
5.1.8 Question 5c 44
5.1.9 Question 6 47
5.1.10 Question 7 49
5.1.11 Question 8 51
5.1.12 Question 9 53
5.1.13 Question 10 59
5.2 Interview 1 analysis 60
5.3 Case study analysis 67

6 Proposed FSMP 74
7 Interview 2 analysis 78
8 Conclusion 82
8.1 Next steps 86
8.2 Learning points 87
9 Contribution to literature 88
10 Timeline and project risks 89
10.1 Research delays 90
11 References 91
Appendix 1 – Relationship of various process safety standards 96
Appendix 2 – Benzole project bow tie diagrams 97
Appendix 3 – SIS safety life cycle overview 100
Appendix 4 – Questionnaire 102
Appendix 5 – Interview 1, process safety manager question set. 105
Appendix 6 – Case study project manager question set 106
Appendix 7 – Interview 2, process safety manager checklist review 107
Appendix 8 – Perceived knowledge liner regression 108
Appendix 9 – Document 70057533-56-FSP-001 - FSMP 110
Appendix 10 – Document 70057533-56-FSP-002 – FSMP schedule 120
Appendix 11 – TSUK FSMS 001 competence 123
Appendix 12 – TSUK functional safety policy 125
Appendix 13 – Proposed FSMP 130
Appendix 14 – Dissertation timeline 136

Table of figures

Figure 1: Safety instrumented level, taken from IEC 61508 (2010) 10
Figure 2: Safety integrated function, taken from Stewart (2019) 10
Figure 3: Completed case study project Benzole storage tank installation. 13
Figure 4: Benzole tanker loading area case study project photograph. 13
Figure 5: IEC 61511 safety life cycle, taken from IEC (2016) 15
Figure 6: Questionnaire distribution and responses 26
Figure 7: Length of service of respondents 27
Figure 8: Age range of respondents 27
Figure 9: Respondents by declared work area. 28
Figure 10: Minitab mean average of functional safety versus respondent high-level groups. 29
Figure 11: Minitab breakdown of group 1 functional safety statistical averages. 30
Figure 12: Minitab breakdown of group 2 functional safety statistical averages 30
Figure 13: Respondents by position 31
Figure 14: Perceived knowledge of each process safety topic 32
Figure 15: Perceived knowledge statistical means by age group 33
Figure 16: Awareness of functional safety management planning 34
Figure 17: Responsibility for each element of the safety life cycle 35
Figure 18: Responsibility for each element of the safety life cycle 35
Figure 19: Cumulative area of responsibility 36
Figure 20: The importance of the life cycle elements 37
Figure 21: Word cloud of most frequent words used to describe hazard identification 40
Figure 22: Word cloud of most frequent words used to describe risk assessment ... 42
Figure 23: Word cloud of most frequent words used to describe layer of protection analysis 44
Figure 24: Layer of protection explanation 46
Figure 25: Word cloud of most frequent words used to describe functional safety management planning. 47
Figure 26: Word cloud of most frequent words used to describe competency. 49
Figure 27: Word cloud of most frequent words used to describe independence in relation to functional safety. 51
Figure 28: Count of importance of various traits for a person conducting verification. 54
Figure 29: Percentage of importance of various traits for a person conducting verification. 55
Figure 30: Verification traits by high level area 56
Figure 31: Minitab statistical average chart for attitude 57
Figure 32: Minitab breakdown of group 3 statistical averages for attitude 57
Figure 33: Verification traits by age 58
Figure 34: Checklist requirement for functional safety management planning 59
Figure 35: Extract of documentation in functional safety DMS 62
Figure 36: Extract from Tata steel UK process safety flow chart 63

Table of tables

Table 1: Worldwide process safety incidents 6
Table 2: COMAH tier 1 substances at case study location 7
Table 3: Fourteen key elements of process safety (Wolters 2019 and OSHA 2023) 8
Table 4: Relationship between high level, distributed and declared areas. 28
Table 5: Number of respondents by position 31
Table 6: Overall position by count 37
Table 7: Overall position by weighted average 38
Table 8: Top ten by age group 39
Table 9: Top ten by high level distribution area 39
Table 10: Top ten words used for hazard identification 41
Table 11: Breakdown of respondents age group and distribution area 42
Table 12: Top ten words used for risk assessment 43
Table 13: Breakdown of respondents age group and distribution area 44
Table 14: Top ten words used for layer of protection analysis 45
Table 15: Breakdown of respondents age group and distribution area 46
Table 16: Top ten words used for functional safety 48
Table 17: Breakdown of respondents age group and distribution area 49
Table 18: Top ten words used for competency. 50
Table 19: Breakdown of respondents age group and distribution area 51
Table 20: Top ten words used for independence in relation to functional safety. 52
Table 21: Breakdown of respondents age group and distribution area 53
Table 22: Verification traits ranked based on total score. 55
Table 23: Breakdown of verification traits by high level area 56
Table 24: Breakdown of verification traits by age 58
Table 25: TSUK process safety verification plan 64
Table 26: TSUK process safety SRS evidence sheet 65
Table 27: 7005733-56-FSP-002 - FSMP competency check sheet. 69
Table 28: 7005733-56-FSP-002 - Completed FSMP (Analysis section) 70
Table 29: 7005733-56-FSP-002 - Completed FSMP (Realisation section) 70
Table 30: Extract from new FSMP checklist front page 75
Table 31: New FSMP detailed stage checklist 76
Table 32: Installation, commissioning, and validation section prior to modification. 79
Table 33: Installation, commissioning and validation section post modification. 79
Table 34: Proposed resource requirements front page. 80

List of acronyms

ACOP	Approved code of practice
ALARP	As low as reasonably practicable
ATEX	Explosive atmosphere directive
CCOHS	Canada centre for occupational health and safety
COMAH	Control of major accidents and hazards
DSD	Descriptive system document
DSEAR	Dangerous substances, equipment and atmosphere regulations
FAT	Factory acceptance test
FS	Functional safety
FSMP	Functional safety management plan
FSA	Functional safety assessment
GDPR	General data protection regulation
HAZID	Hazard identification
HAZOP	Hazard and operability study
HRP	Hot rolled products
HS	Hazard study
HSE	Health & safety executive
IPL	Individual protection layer (barrier)
LOC	Loss of containment
LOPA	Layer of protection analysis
LPG	Liquid petroleum gas
OSHA	Occupational safety and health association
PCA	Process control and automation
PHA	Process hazard analysis
PLC	Programmable logic controller
PM	Project manager
PS	Process safety
PSM	Process safety management
PSSR	Pre-start up review
RA	Risk assessment
SAT	Site acceptance test
SIF	Safety integrated function

SIL	Safety integrated level
SIS	Safety integrated system
SRS	Safety requirement specification

1 Background

Process safety is a generalised “umbrella” term used to capture all the various directives, regulations and standards in place to prevent explosions, fatalities, fires, injuries or unexpected hazardous material releases within the process industry. Appendix 1 visualises this and shows the relationship between the regulations and occupational safety.

1.1 Process safety issues

Process safety incidents are extremely low frequency with exceedingly high severity this is contrasted by occupational safety incidents which are high frequency and low severity. Process safety incidents however are more common than the industry would like, fortunately most incidents end up as near misses where the full potential of the incident has not been realised, for example a quantity of gas leaks in an open space at a height and disperses directly into the atmosphere.

Table 1 highlights some of the worst process safety incidents seen throughout the world over the last 50 years.

Date	**Location**	**Incident**	**Fatalities**	**Injuries**
1 Jun 1974	Flixborough, UK	Caprolactam production plant, gas release	28	
19 Nov 1984	Mexico City, Mexico	LPG storage tank explosion	500	700+
3 Dec 1984	Bhopal, India	Carbide plant, gas release	3000	100000+
28 Apr 1986	Chernobyl, Ukraine	Nuclear power plant radioactive leak	56	100000+ fatalities since
6 Jul 1988	Piper Alpha, North Sea	Oil production platform explosion	167	

23 Oct 1989	Phillips, Pasadena, Texas	Polyethylene reactor gas release	23	300
1 Feb 2003	Columbia, Texas	Space shuttle explosion	7	Two thousand square miles debris
23 Mar 2005	BP Texas City, USA	Oil refinery explosion	15	180
11 Dec 2005	Buncefield, UK	Vapour cloud explosion	0	43
20 Apr 2010	Macondo, Gulf Of Mexico	Deep water drilling rig explosion	11	87 days uncontrolled oil spill
11 Mar 2011	Fukushima, Japan	Nuclear reactor, gas release	0	
7 May 2020	Visakhapatnam, India	Chemical plant leak	12	1000
4 Aug 2020	Beirut, Lebanon	Warehouse explosion	200	6500
29 Mar 2021	West Java, Indonesia	Oil refinery	0	5 and 1000 Evacuated

Table 1: Worldwide process safety incidents

The continued pattern of serious events led to greater emphasis on process safety and dangerous substances, eventually leading to the DSEAR 2002 regulations being created to ensure adherence to the ATEX 1999 directive for explosive atmospheres.

1.2 Process safety

CPS (2023) define a process safety incident or event as:

"An event that is potentially catastrophic, i.e., an event involving the release or loss of containment of hazardous materials that can result in large-scale health and environmental consequences."

Wolters (2019) defines process safety management (PSM) as:

"A standard that requires employers to identify, evaluate, and control the hazards associated with the highly hazardous chemicals used in their processes."

Under the control of major accident hazard regulations 2015 Port Talbot steel works is classified as a COMAH Tier 1 site. This means they hold vast quantities of dangerous substances. Some of the substances that can be found within the Tata site are seen in Table 2.

Substance
Blast Furnace gas
Coke Oven gas
Hydrogen
Benzole
Ammonia
Oxygen
Heavy fuel oil

Table 2: COMAH tier 1 substances at case study location

Wolters (2019) and OSHA (2023) detail fourteen key elements required within process safety management to avoid process safety incidents, which are detailed in table 3.

1	Process safety information	Employers must develop written safety information before conducting a PHA.
2	Process hazard analysis	Employers must identify, evaluate, and control hazardous processes.
3	Operating procedures	Employers must develop and implement written operating procedures.
4	Incident investigation	Thorough investigations must be completed anytime there is an incident associated to the process.
5	Management of change	Changes to a process must be evaluated to determine if there will be any impacts on the health and safety of employees
6	Mechanical integrity	Process equipment must be designed and installed correctly.
7	Employee participation	The employer must involve workers in PSM programs.
8	Trade secrets	Employers must provide all information necessary to comply with PSM standards, regardless of the trade secret status of the information
9	Training	Employers must train employees on hazards and procedures.
10	Contractors	All contractors working on, or near highly hazardous chemicals must be trained on emergency procedures and other relevant aspects of the PSM program.
11	Hot work	Hot work permits must be issued for any hot work operations taking place near the process.
12	Pre-start-up safety review	The PSSR must be conducted for new and modified facilities before operations can begin.
13	Emergency planning	Employees must be trained on emergency planning and response procedures.
14	Compliance audits	Audits must be conducted and reported at reasonable intervals.

Table 3: Fourteen key elements of process safety (Wolters 2019 and OSHA 2023)

1.3 DSEAR

The DSEAR regulations 2002 underpin the ATEX 1999 directive and were modified in 2015 to include under pressure gasses and the EU regulations concerned with protection and prevention of risks from explosion, fire and similar events that can arise form dangerous substances, used or stores within a workplace. The DSEAR regulations are enforceable within the UK by the HSE (HSE, 2023).

Davies (2023) suggests that by following the DSEAR regulations you can prevent any potential future disaster from dangerous substances. The UK government contradicts this by suggesting risks must be either be eliminated or reduced as far as is reasonably practicable (Gov.uk, 2020). Reasonably practicable involves weighing a risk against the trouble, time and finance needed to control it. This infers an element of risk will always be present but managed.

Appendix 1 shows the relationship between each of the directives, regulations and standards included under the process safety umbrella.

1.4 Relevant standards - IEC 61508 and IEC 61511

Éclair (2023) suggest IEC 61508:2010 was introduced to provide a generic approach for all lifecycle activities comprising of electrical and or electronic elements used to implement safety functions. This has been defined by the HSE as the general benchmark of good practice. Bell (2017) however suggests this only covers the safety related design of hardware and software hence the introduction of IEC 61511 to cover functional safety instrumented systems for the process industry sector.

A safety instrumented system (SIS) is implemented to reduce the existing risk level identified in the process hazard analysis (PHA) to a tolerable level identified by the business after the passive layers of protection have been identified within the layer of protection analysis (LOPA). This gap is the safety integrated level (SIL) the system needs to match or better as demonstrated in figure 1.

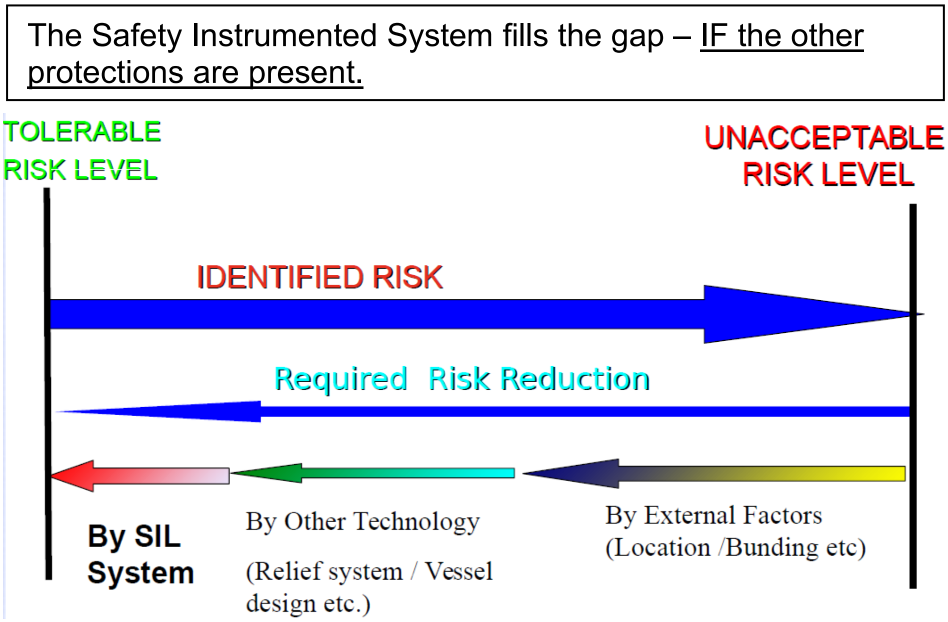


Figure 1: Safety instrumented level, taken from IEC 61508 (2010)

A SIS is a system of several safety integrated functions (SIF) electronic protection layers designed to meet the SIL (probability that the SIF will not work when required) and comprise of a sensor, logic solver and final element. Figure 2 shows a single rudimentary safety integrated function.

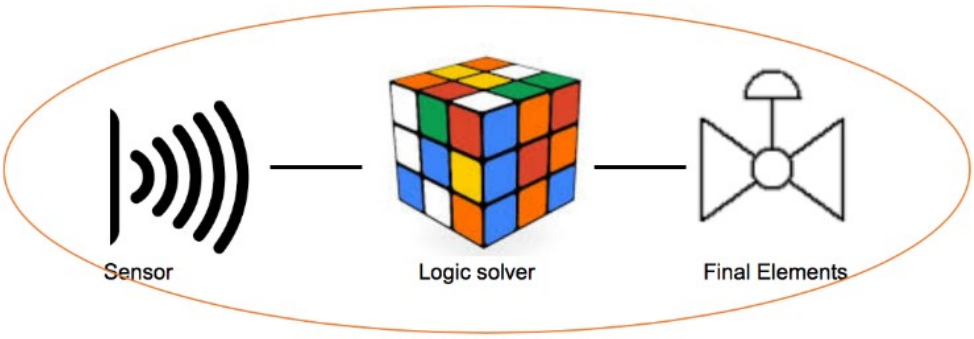


Figure 2: Safety integrated function, taken from Stewart (2019)

1.5 Case study

A review of the functional safety management plan (FSMP) created for the Benzole upgrade project within Port Talbot works, a COMAH tier one site. The project commenced in May 2021 and was due for completion in August 2023. The project identified two individual process safety intolerable scenarios; the first scenario is a loss of containment (LOC) of Benzole at the Benzole storage area resulting in a fatal explosion and the second scenario is a LOC of Benzole at the Benzole loading area, again resulting in a fatal explosion. The bow tie diagram as seen in appendix 2 details the preceding events to the high-level event and the consequential modifiers to reduce the effect once initiated. The worst case for both events is a pool fire and toxic cloud that could result in three fatalities.

The case study project was to replace both existing Benzole storage tanks and tanker loading system with new. The system originally included eleven SIL loops, which was reduced to seven on revision two of the LOPA, Table 4 shows each of these seven loops in detail. Each of the seven off SIL one loops, has a detailed description of which sensor when reaching a certain value, tells the logic solver, a PLC in this case, to close a final element i.e., valve XSV13902.

SIF	Allocation of Safety function to protection layers (LOPA)	SIF Description	SIL
PTC0101	Benzole Storage & Tanker loading upgrade LOPA Report	Benzole Storage TK119 Overfill: Benzole storage TK119 High High level (1oo1 level transmitter LT13917 @>90%) closes XSV13902	SIL 1
PTC0102	Benzole Storage & Tanker loading upgrade LOPA Report	Benzole Storage TK120 Overfill: Benzole storage TK120 High High level (1oo1 level transmitter LT13918 @>90%) closes XSV13904	SIL 1
PTC0107	Benzole Storage & Tanker loading upgrade LOPA Report	Benzole Tanker loading Overfill protection. Tanker high level or earth not proven alarm (1oo1, XA13740) closes XAV13737	SIL 1
PTC0108	Benzole Storage & Tanker loading upgrade LOPA Report	Benzole Tank Storage Leak with tank filling. Benzole leak detection High (1oo2, AT13720 or AT13721 @>300ppm) closes XSV 13902 AND XSV13904	SIL 1
PTC0109	Benzole Storage & Tanker loading upgrade LOPA Report	Benzole Tank Storage Leak with tank discharging. Benzole leak detection High (1oo2, AT13720 or AT13721 @>300ppm) closes XSV 13701 AND XSV13702	SIL 1

PTC0110	Benzole Storage & Tanker loading upgrade LOPA Report	Benzole loading pump Leak. Benzole leak detection High (1oo1, AT13732 @>300ppm) closes XSV 13737	SIL 1
PTC0111	Benzole Storage & Tanker loading upgrade LOPA Report	Benzole Tanker loading LOC. Benzole leak detection High (1oo4, AT13722, AT13723, AT13724 or AT13725 @>300ppm) closes XSV 13737	SIL 1

Table 4: Case study seven SIL loops.

Table 5 shows some of the key information relating to the case study project. Whilst this is high level it can be seen that the overall project from approval to completion was just over two years with a total expenditure of £7.87 million. The project was five months over the predicted completion date of March 2023 due to contractual issues around functional safety. The project incorporated six independent contracting companies collaborating with each other, with typically ten persons on site each day. Over the entire period only one minor occupational injury was sustained.

Total Investment Cost	**£7.87M**
Project ID	**2000467**
Project Approval	**Apr-21**
Planned Completion date	**Mar-23**
Actual Commissioning Date	**Jul-23**
Handover to operations	**Aug-23**
Variation Orders	**11**
Contracting Companies used	**6**
Total Accidents	**1**

Table 5: High Level case study project key details

Figures 3 and 4 are high level views of the completed project, Figure 3 shows the two off new 186000L Benzole storage tanks. Figure 4 shows the tanker loading area with water and foam deluge system around where the tanker is parked for loading.

Figure 3: Completed case study project Benzole storage tank installation.

Figure 4: Benzole tanker loading area case study project photograph.

2 Aim & objectives

2.1 Aim

To investigate the effectiveness of functional safety planning, verification, validation and competence throughout the entire process safety lifecycle.
Case Study: Tata Steel, Port Talbot works.

2.2 Objectives

1. To critically evaluate the effectiveness and complexity of current functional safety planning specifically around competence, validation, verification, and the use of checklists.
2. To assess the current knowledge level of functional safety, demonstrable competency, validation, and verification within Tata steel Port Talbot.
3. To critically evaluate the current functional safety planning system, verification, validation and competence during the implementation of a project.
4. To propose, assess and evaluate a checklist of items to implement within a functional safety plan and produce a standard proforma that can be applied in any future functional safety plan that captures validation, verification and competence.
5. Identify future research from this proposal.

The next section identifies the literature already present around functional safety and critically evaluates this around how industry approaches functional safety planning, demonstrating competency, validation and verification and the use of proformas and checklists when creating plans.

3 Literature review

To deliver the first objective of the research presentation, the literature review will focus on the following topics.

- Functional safety legislation
- Functional safety planning in industry
- Demonstrating competency, validation, verification, and independence
- Use of proformas or checklists in creating plans

3.1 Functional safety legislation

Functional safety within process industries is covered by the standard IEC 61511 – functional safety and safety instrumented systems for the process industry sector. Whilst not legislation, the UK HSE deems this as best practice under ACOP L138.

IEC 61511 encompasses the full safety life cycle of a safety integrated system (SIS) within the process industry. figure 5 represents the key elements of the safety life cycle.

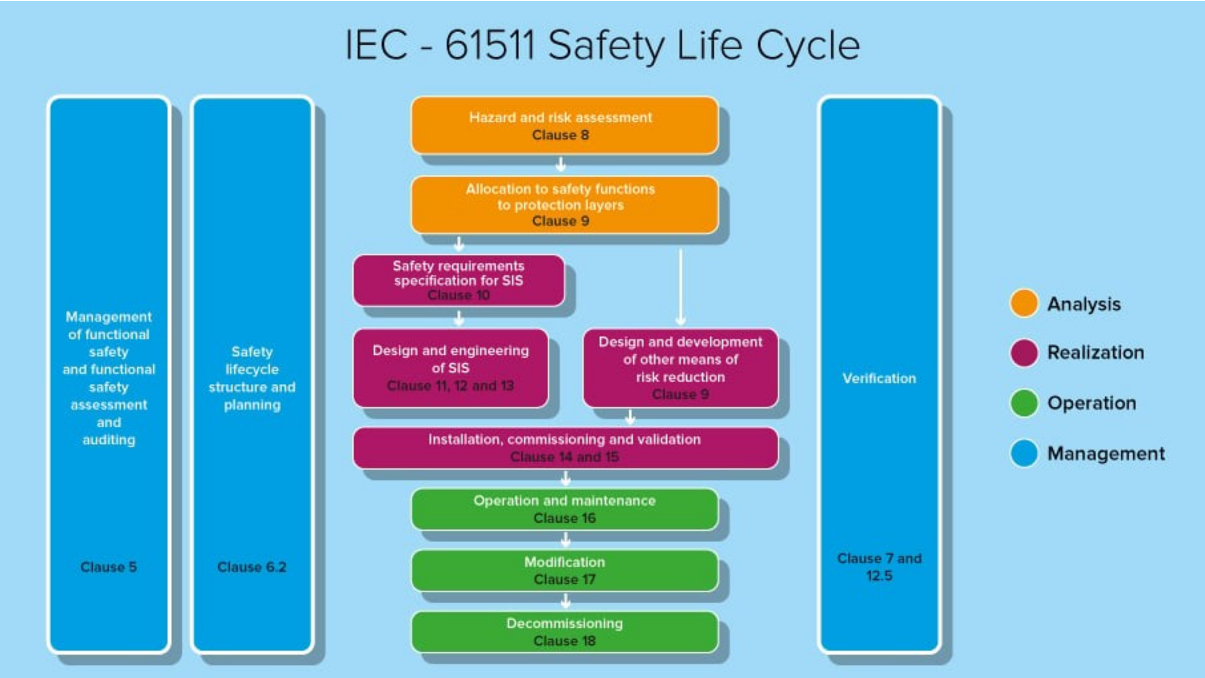


Figure 5: IEC 61511 safety life cycle, taken from IEC (2016)

GM International (2021) suggests that many projects involving functional safety and SIS get off on the wrong foot by applying the false assumption that copying the lifecycle from the standard could be enough.

Dearden (2016) suggests that the functional safety world is full of scaremongering and most of the information available is incorrect. Exida (2023) suggests that although functional safety was introduced in the late nineteen nineties, thirty years later, industry regards these as new and is still learning to apply them effectively.

3.2 Functional safety planning in industry

Knight (2005) suggests that the functional safety management plan (FSMP) is the single key document in any IEC 61508 or IEC 61511 development project. The FSMP specifies how functional safety will be delivered throughout the entire safety life cycle from development through testing, installation, in production through to modification and finally decommissioning.

The functional safety management plan identifies the various roles and responsibilities as they apply to the process stages. In contrast the competence and independence behind these roles is left to the end user to define. The functional safety management plan lists the various techniques and measures that will be implemented as part of the project to ensure that the targeted SIL is achieved and can be maintained. Exida (2023) however believe the FSMP should fully define the roles, responsibilities, competencies, documentation requirement, verification criteria for each aspect of the life cycle.

The deliverable of this task is the FSMP that the customer produces must subsequently be regularly reviewed; refined through their document management process and implemented and updated throughout the entirety of a functional safety project.

Section 6.2.2 of IEC 61511 details a table for each of their proposed eleven phase of the safety life cycle including a high-level view of the objectives, requirements, inputs, and outputs which can be seen in appendix 3. Whilst this appears to provide a comprehensive approach it does not detail the exact documents required for each stage. Section 6.2.3 further explains that the safety plan shall include the techniques, measure, procedures, and responsible persons for ensuring the SIS safety requirements are achievable for all relevant stages of the process, the SIS is professionally installed and commissioned, maintaining the safety integrity during operations, and managing the process hazards during maintenance of the SIS.

IEC 61511 suggests the FSMP should be created at the onset of a project. Method (2023a) however believe there should be a high-level plan created at the onset of the project indicating the competence of the people required throughout the project and the detail behind the first phase, the detailed plan for each lifecycle stage could be developed on a phase-by-phase approach.

3.3 Demonstrating competency, validation, and verification.

IEC 61511 Section 5.2 relates to the management of functional safety, the organisation, and resources. Section 5.2.2 states persons involved within the SIS safety life cycle shall be competent to conduct the activities for which they are accountable. Smith et al (2004) suggest IEC 61508 Annex B does not sufficiently cover competence needed but suggests that relevant training, knowledge, and experience is required.

The latest, 2016 version of the IEC 61511 standard now highlights several aspects of competency that should be considered including engineering knowledge and experience; Safety engineering knowledge; legal and regulatory functional safety requirements; adequate leadership and management skills; understanding of the consequence of an event; understand the SIL of the SIF and the complexity of the application and technology. With a regular review cycle to manage ongoing competency. Smith et al (2004) suggests this is too vague but this still misses the relevance of previous experience, and the qualifications needs to be highlighted as these changes in each life cycle phase.

Competence definition:
"*Competence is the combination of practical & theoretical knowledge; cognitive skills and behaviours used to perform a specific role*."

White (1959)

The White (1959) definition is backed up by both Cabletalk (2023) and the National Institute of Health (2023) who suggest knowledge is information developed or learned and demonstrated through formal exams. Skill is the result of repeatedly applying this knowledge and behaviours demonstrate the observable reaction to a certain situation. Cabletalk (2023) take this definition further suggesting demonstrating competency is a continuous process and the responsibility of both the employer and employee.

TUV (2023a) are one of the world's leading certification bodies that certify persons as competent within IEC 61508 & IEC 61511. TUV (2023a) back the Cabletalk (2023) definition up by confirming their competence certification is a qualification aimed at the regulations and a company should also have a method of proving competence of their individuals.

Method (2023) suggest that the functional safety standards, use the following elements for demonstrating competence.

Experience : The amount of time you have been involved in doing something.
Formal Training : Have you been taught to do the task correctly. Ideally through a task specific training course.
Demonstration of knowledge : The application of training and experience to demonstrate to others you know how to do things correctly and actually do them correctly in practice. Can be through exam or peer review.

GM International (2021) suggest that all these definitions are virtually identical, where, i.e., experience is skill, knowledge is formal training and behaviour is demonstration of knowledge, but the functional safety identification of competence makes the demonstration of competence more quantitative than qualitative.

ESC.UK (2023) suggest that purely looking at skills, knowledge and behaviour can be misleading. A person who has been employed for twenty years as an electrical engineer who has never had an accident could be classed as competent to write an electrical permit for example. Alternatively, a BS EN 7671 qualified electrical engineer who has completed an electrical permit training course and provided a minimum of three peer reviewed electrical permits and reassessed on a rolling three-year process would be a much better qualitative approach to defining competency.

Method (2023) further spilt competency into three levels, although their documentation suggests four levels, this includes the Junior role, which as they state is everyone's base level so not really a competency level.

Professional: Understand what good looks like, but still need support or mentoring to complete tasks.
Master: Demonstrated competence and is minimum level to conduct a task without mentoring.
Expert: Very competent in task and is able to train others.

Tata use a similar hierarchical system of awareness, practitioner and expert which are aligned to methods professional, master, and expert level.

These three levels clearly distinguish the differences and provide a ladder to becoming an expert in a competence. The levels allow a company to easily identify training gaps and needs for each competence however every company needs to understand that there will always be individuals at each stage of the process and not everyone will move up the competence ladder to become experts. Many companies will only ever need a handful of experts to ensure the standards around competence do not become diluted. Tata typically have one or two nominated experts in each works area that provide the competency training and sign off process, where possible these people are independent to the daily operations of the plant to reduce bias.

IEC 61511 Section 5.2.6 details the process around functional safety assessments (FSA) and the assessment shall be done by a team where at least one person is independent by not being involved in the design stage for FSA 1, 2 & 3 and at least one person is independent by not being involved in the operation or maintenance for FSA 4 & 5.

IEC 61511 section 7 covers verification process in detail and starts introducing concepts around independence within the FSMP. IEC 61511 Section 7.2.1 states verification planning within the FSMP shall address the level of independence for persons conducting verification.

Verification can be defined as:

> " *A process used to evaluate whether a product, service or system complies with regulations, specifications or conditions exposed at the development stage*."
>
> IEEE (2016)

ESC.UK (2023) suggest that verification is the activity of demonstrating for each phase relevant of the safety lifecycle, that, for the specific given inputs, the outputs meet the requirements for the specific phase.

IEEE (2016) suggest that verification is typically in internal process. In the example of verification in a process it is not the verifiers responsibility to ensure that the correct output is achieved from the process but ensures the relevant input documentation; legislative requirements; competent people and process was in place and followed to allow the team conducting the process to have produced the right answer.

Method (2023a) suggest the IEC 61511 does not provide guidance on the requirements for verification but focuses on ensuring verification is planned and completed. This allows freedom to users to verify as they see fit, a checklist can be a useful tool for verification, assuming it is completed by competent people and is planned in advance.

Method (2023a) further suggest companies use verification and validation plans (V&V plans) which cover both verification and validation as one. Method (2023a) suggest this approach should not be used as there is a significant difference between these activities in activity frequency, duration and competence requirements. Validation is only a requirement for the FAT and SAT tests, whereas verification is a requirement at every stage of the lifecycle.

IEC 61511 Section 15 covers safety system validation with section 15.2.1 suggesting the FSMP shall include the level of independence required for validation activities.

Validation can be defined as:

"*To ensure a product, service or system results in a product, service or system that meets the operational needs of the user*."

Soliman (2011)

This means a product works as intended in the case of functional safety, the safety integrated system meets and delivers the requirement of the safety requirement specification (SRS) or as Ronseal (1994) advertising slogan describes, it does what it says on the tin.

KVA (2023) suggest verification and validation are commonly confused for one another whilst each of them actually serves an extremely specific purpose. Verification answers the question: "Did we build the system right?" where validation answers the question: "Did we build the right system?"

Esc.uk (2023) suggest validation is the activity of demonstrating that the safety related system constructed, meets in all respect the safety requirement specification for that safety related system.

Wetherill (2023) suggests that as validation itself is a task, which needs verifying and independence needs to be included at this stage too.

ESC.UK (2023) suggest there are three levels of independence they are :

- Independent person
- Independent department
- Independent organisation

ESC.UK (2023) further suggest that the level of independence required is relative to the SIL level identified in the SRS. A SIL level of one would require an independent person, SIL level two would require an independent department and SIL level three or above require an independent organisation to sign off the SIL as compliant.

Tata follow a very similar process, where SIL level one; two and three are all verified (checked) by an independent person within the process safety department. The process safety department is a central department not linked to any manufacturing area, hence having independence and SIL level four would be externally verified by a competent third party. Even though SIL four would be externally verified the central process safety department would also complete verification, like a check the checker process.

3.4 Use of templates or checklists as a base for planning

Knight (2005) suggests that under clause nineteen the requirement for information and documentation, to achieve compliance the end user must understand the requirement and define their own procedures and process to meet these requirements. This can lead to key aspects being either missed completely or misconstrued. Mukundan et al (2009) suggest that checklists used in textbooks need to be quantitative to ensure adherence and effectiveness but can quickly become outdated as there is no means to update them.

Jenson et al (2007) suggest templates are a reliable source of knowledge transfer between persons especially where teams are fractious. Celik (2022) further suggests templates used in the education sector helped the inexperienced to develop complex lesson plans in an efficient timely manner.

Method (2023a) has already suggested that checklists are an appropriate tool for verification as such there no should be no reason a checklist should not be used for every other stage of the safety lifecycle.

TUV (2023a) suggest for a fee a functional safety toolkit package could be purchased which would include a range of important safety checklists to provide a thorough overview to ensure regulation compliance. Mathworks (2023) however suggest the toolkit is aimed at component design validation and verification to meet IEC 61508, the competences and level of verification and validation is different to the requirements of IEC 61511. An additional fee for a toolkit would deter most companies from purchasing as the detail and relevance is unknown.

The next section highlights the methodology used to complete the research, using both qualitative and quantitative measures.

4 Methodology

To complete this dissertation a case study will be completed, identifying the current gaps in functional safety legislation, industrial implementation of functional safety planning and how this this incorporated with the Tata steel plant at Port Talbot.

Objective one has been completed by the literature review and any gaps identified have been used to create question sets to complete the remaining objectives.

To deliver objective two, a mixed methodology technique will be used. Firstly, a questionnaire will be produced which will incorporate a mixture of both quantitative and qualitative questions and delivered to a sample of the electrical; process control; project and safety employees to understand their perception of functional safety planning, competence, validation, and verification (see appendix 4). The sample group was chosen from the total population as these individuals interact with functional safety on a frequent basis and should provide valid and valuable results. Eighty questionnaires will be issued and distributed through seven area engineering managers to disseminate to their direct employees that work in or around a COMAH area, this removes any bias which may be introduced in the selection of individuals. Walliman (2005) suggests that questionnaires can be a cheap and effective way of collecting large amounts of data but have limitations such as the inability to ask probing questions. The same questionnaire will also be delivered to two local engineering contracting firms through their site managers who are used on site and who constantly work on projects that involve functional safety. Nulty (2008) et al suggest that an average response rate of 32% is typical for questionnaires but due to the Author's influence this is expected to be to be higher.

Secondly, a semi-structured interview will be held with the Tata steel process safety manager to obtain both quantitative and qualitative data of their understanding of functional safety; the perceived competence of the workforce; the effectiveness and implementation of the current Tata functional safety policy in place; and discuss any opportunities identified from the completed questionnaires and the case study review through several open ended questions as seen in appendix 5. Adams (2015) suggest this type of interview is suited to single respondents where open or closed questions can be followed up with how or why. Leavy (2014) suggests limiting the interview time to a maximum of one hour to avoid interviewer and respondent fatigue.

To deliver objective three, the functional safety plans from the selected case study project, originally due for completion in March 2023, but delayed until August 2023 will be critically evaluated to identify gaps between the Tata procedures; current legislation and current knowledge identified during implementation. A semi structured interview, see appendix 6 for the question set, will be held with the project manager to obtain both quantitative and qualitative data of their understanding of functional safety and the effectiveness of functional safety management planning implementation throughout the various lifecycle phases within the project.

The fourth objective will be delivered by a second, this time unstructured interview with the Tata steel process safety manager to obtain their views of the Author’s findings and the proposed checklist of an ideal functional safety plan that covers the key aspects of competence, verification and validation. Although unstructured, appendix 7 identifies the basic questions to be asked within this interview.

The fifth and final objective will be compiled from the learnings, results and conclusions and formulated in a list of next steps.

In all interview cases the anonymity and confidentiality of the interviewees will be maintained. The Author has had verbal agreement with the interviewees that the results can be used within this research.

The next section analyses the data from the questionnaires, interviews, and case study.

5 Results and analysis

5.1 Questionnaire analysis

5.1.1 General data

Eighty questionnaires were distributed through seven engineering managers, Sixty questionnaires were returned within the allotted period which provided a 75% rate of return. Nulty (2008) suggests the typical return rate expected is 32%, the return rate in this instance is much higher as the Author had direct influence with the area managers and could encourage them to ensure their team completed and returned the questionnaires within the time frame allowed. Figure 6 shows the questionnaire distribution and response rate in numbers but also identifies that nine (15%) of the returned sixty questionnaires were not completed correctly and so removed from the analysis. This meant that only fifty-one (63.75%) of the questionnaires sent out had meaningful data.

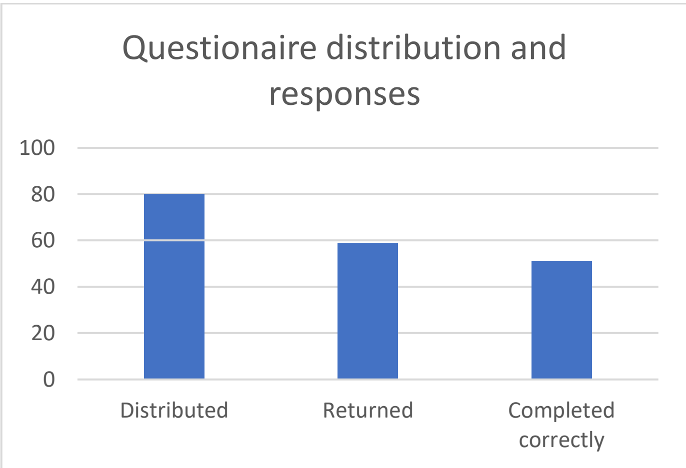


Figure 6: Questionnaire distribution and responses

Due to Tata's restructuring announcement during the questionnaire stage, both external companies declined the opportunity to participate with the research questions.

Figures 7 and 8 show the length of service and age range of the respondents. Tata has a workforce that is both aged but with lots of experience. Thirty-five percent of respondents had both over twenty-one years of experience and were fifty years old or above. Whilst the survey focused on the electrical engineering team these levels of service of, and age are mirrored throughout the engineering and production fraternity.

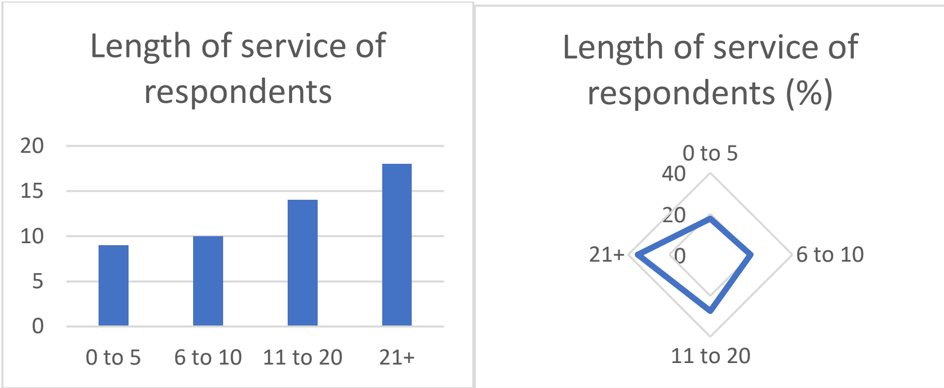


Figure 7: Length of service of respondents

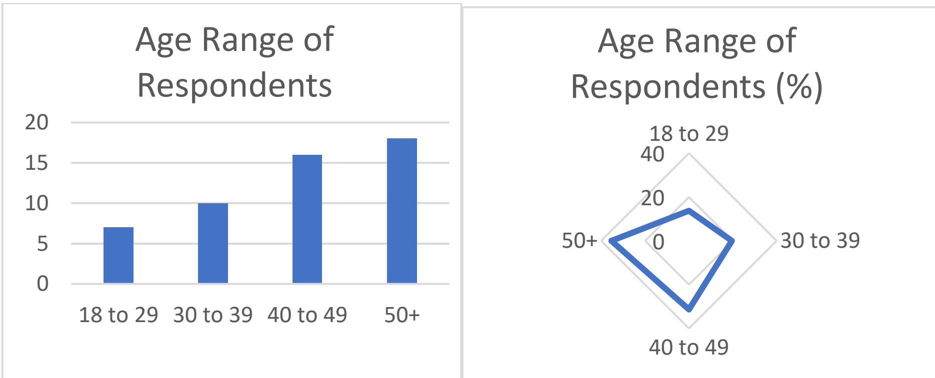


Figure 8: Age range of respondents

Although the questionnaires were distributed to seven area managers, the responses highlight thirteen different work areas. Table 4 shows the relationship between the seven distribution areas where questionnaires were sent to and the thirteen declared areas in the responses. Table 4 also shows the high-level grouping that is used for statistical analysis in Minitab, this was required to ensure a concise comparison could be made between respondent's answers. Figure 9 shows the split of respondents by work area and a cumulative percentage total of respondents.

High Level	Distributed area	Declared work area	Respondents
Coke, Sinter & Iron (1)	Coke, Sinter & Iron (1)	Coke Ovens (1)	7
		Sinter Plant (2)	2
		Blast Furnaces (3)	5
		Coke, Sinter & Iron (4)	5
		Harbour (5)	4
Central (2)	Central Safety Department (2)	Process Safety (6)	4
		Central Safety (7)	4
	Projects department (3)	Projects department (8)	4
Other manufacturing Areas (3)	Steel and Slab (4)	BOS Plant (9)	3
	Hot Rolled Products (5)	Hot Rolled Products (10)	3
	Cold Rolled Products (6)	Cold Rolled Products (11)	3
Central (2)	Central Engineering (7)	Infrastructure (12)	3
		DSEAR (13)	4

Table 4: Relationship between high level, distributed and declared areas.

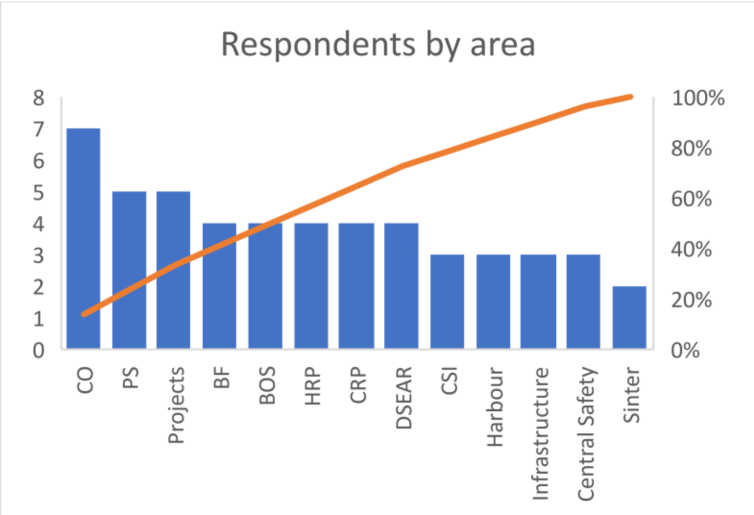


Figure 9: Respondents by declared work area.

The declared work areas allowed for a more in-depth analysis of trends where applicable.

Coke, Sinter, and Iron as a department is the largest department within the works and unsurprisingly provided twenty-three (45.1%) of the questionnaire responses. Whilst this could be seen as a skew in the results, with the exception of the Harbour the remainder of the Coke, Sinter and Iron department are the biggest process safety areas within the works as they use the largest volumes of gasses and have the most hazardous by products.

Minitab identified a statistical difference in the responses between high level areas for functional safety, this can be seen in figure 10 where group 1 (Coke, sinter &iron) are below the mean and group 3 (Other manufacturing areas) above the mean.

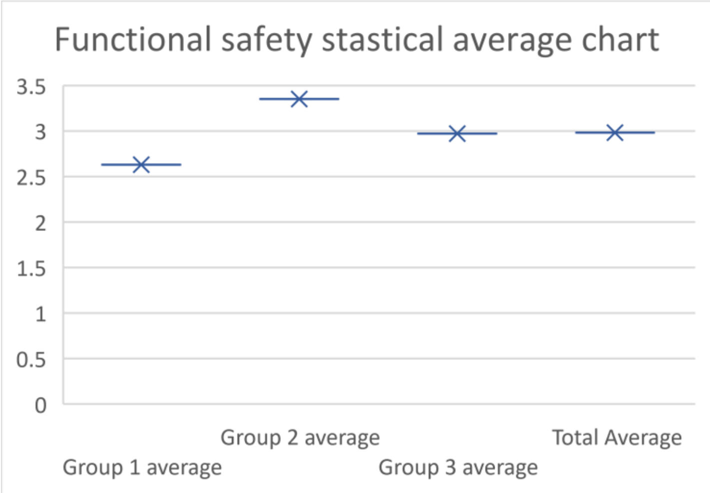


Figure 10: Minitab mean average of functional safety versus respondent high-level groups.

These were further analysed and figure 11 shows the results that the group 1 (Coke, sinter & iron) perceived functional safety knowledge was reduced due to a low score from respondent group 5 (Harbour) this would be expected as the Harbour is the lowest process safety and functional safety risk within Tata steel, so their knowledge is expected to be lower. Figure 12 shows that the group 2 (Central) perceived knowledge is higher than the total mean because of respondent group 13 (DSEAR team) again this is expected that as this team live and breathe DSEAR including functional safety, their perceived knowledge should be higher. It is noted that the project departments and central safety also have a higher than average perceived knowledge, it could be suggested that all the above averages scores are attributed to the recent case study which led to several persons being trained specifically in functional safety within these departments.

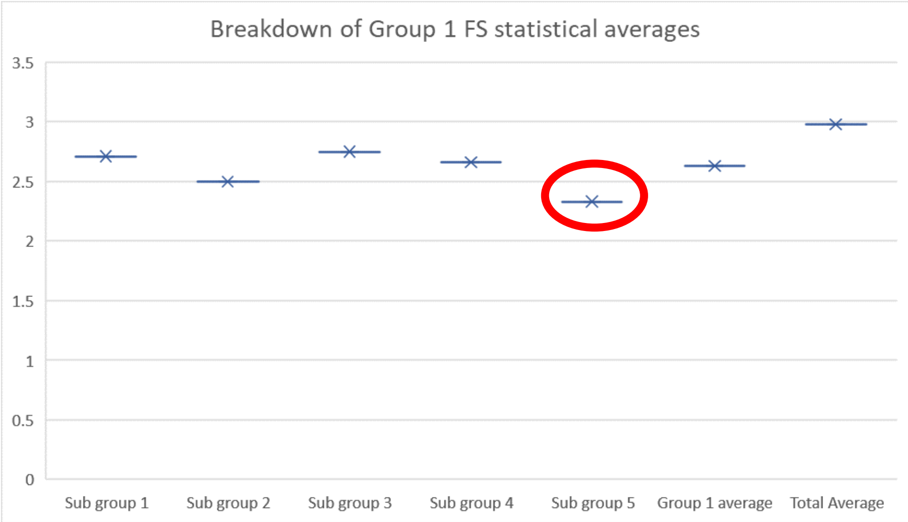


Figure 11: Minitab breakdown of group 1 functional safety statistical averages.

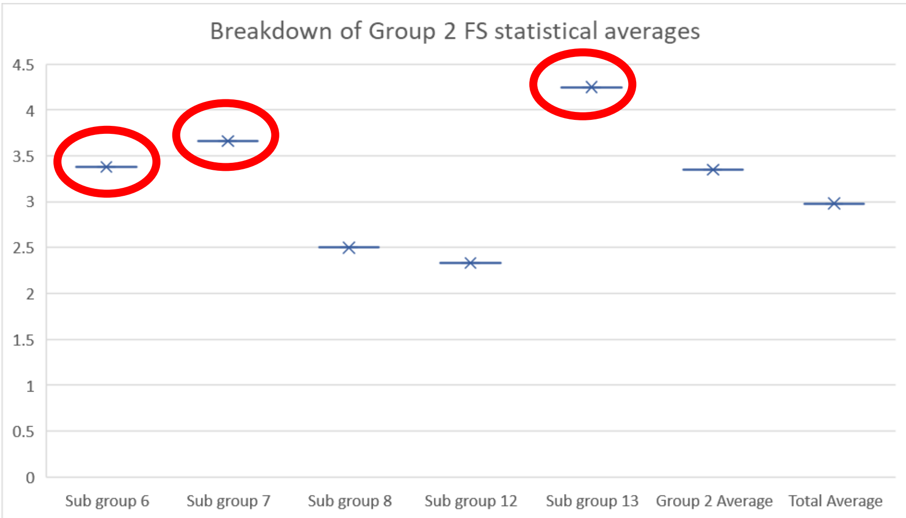


Figure 12: Minitab breakdown of group 2 functional safety statistical averages

Table 5 shows that of the fifty-one respondents, fifteen (29.4% see figure 13) classed themselves as electrical engineers. This level of responses of persons classing themselves as electrical engineers is expected as throughout Tata steel the term electrical engineer has been used as an umbrella term to cover all disciplines within the electrical fraternity irrespective of expertise. For example, and electrical engineer could have expertise in high voltage; automation; controls; instrumentation; commissioning; installation or be a generic plant engineer in charge of a discrete area of plant.

Position	Respondents
Electrical Engineer	15
Departmental Engineer	1
Electrician	7
Shift Engineer	7
Process Safety Engineer	3
Process Safety Graduate	2
Project Engineer	5
PCA Engineer	5
Safety Facilitator	2
Manager	1
Engineering Technician	2
Safety Engineer	1

Table 5: Number of respondents by position

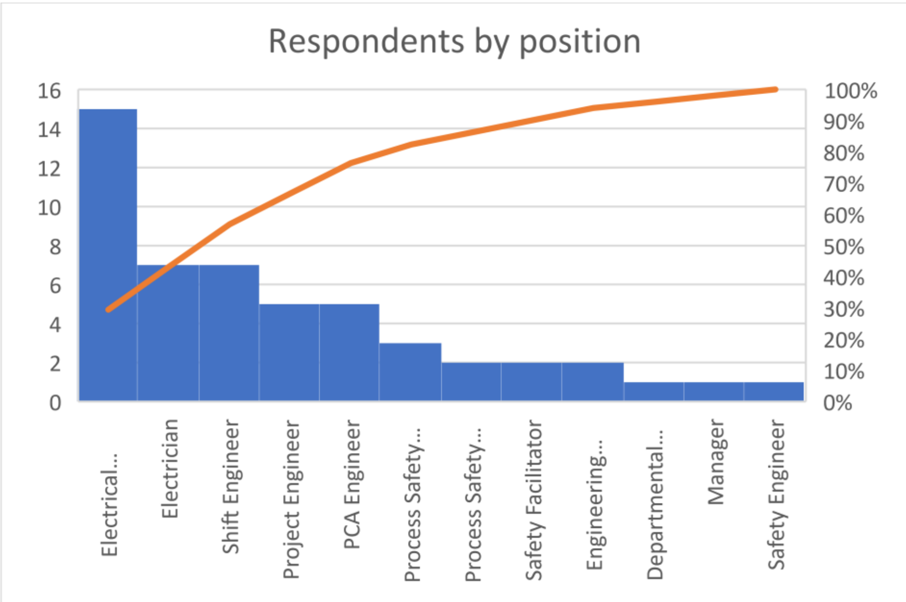


Figure 13: Respondents by position

5.1.2 Question 1

The first question asked was to ascertain what the perceived knowledge of the respondents is for the fundamental areas covered under the process safety umbrella. Figure 14 depicts the perceived knowledge of each topic by age group.

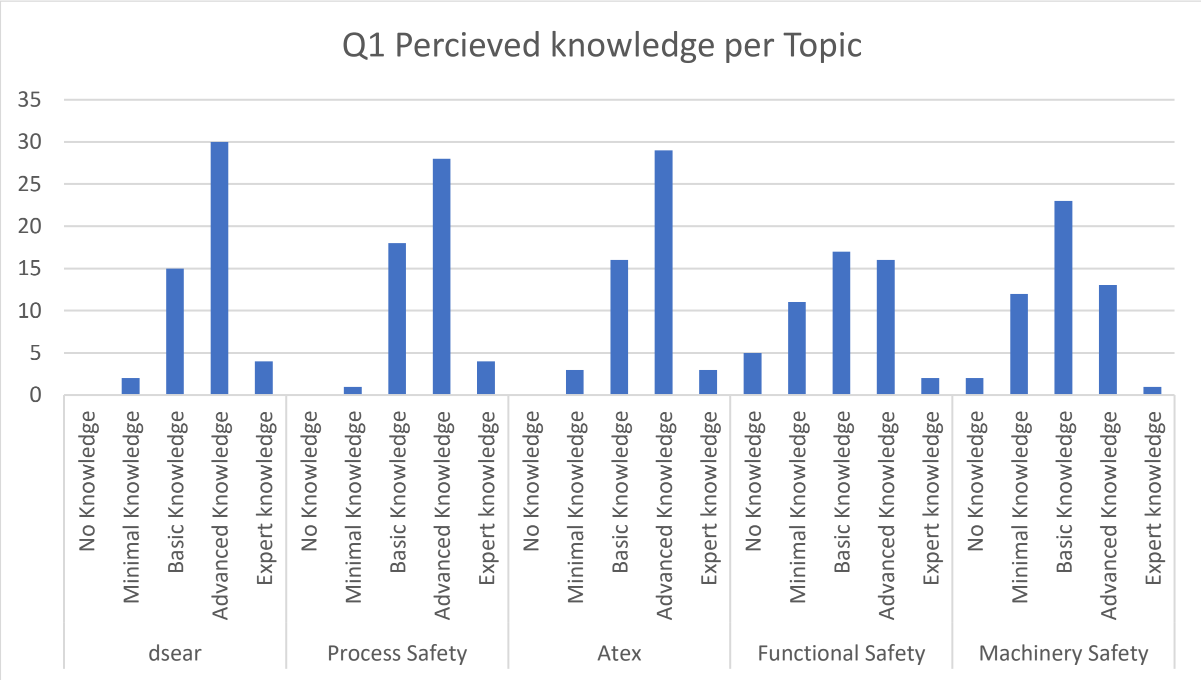


Figure 14: Perceived knowledge of each process safety topic

Perceived advanced knowledge of functional safety reduces from an average of 57% for DSEAR, process safety and ATEX to 27% for functional safety and machinery safety. This suggests that further awareness and training around the subject is needed and a checklist identifying the key stages and associated documentation would be beneficial.

The data also suggests there is a positive correlation see appendix 8 between age of the respondent and level of perceived knowledge, where the older the respondent the greater the perceived knowledge they have within the topic. Figure 15 confirms this, which is what would be expected as a person's knowledge would be expected to increase the longer, they have worked in that field.

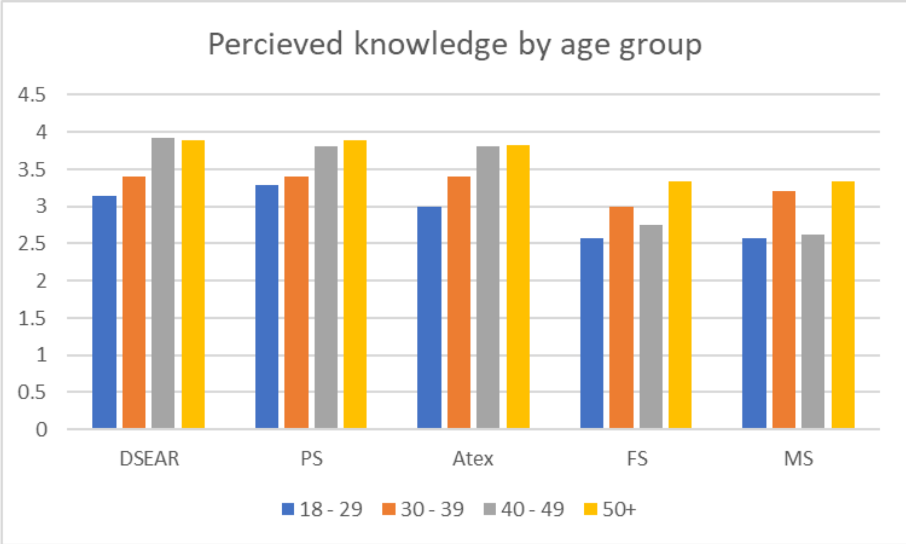


Figure 15: Perceived knowledge statistical means by age group

However, figure 15 further identifies that functional safety and machinery safety are the exception. Perceived knowledge in these areas the reverse is seen where a negative correlation, see appendix 8 between the respondents age and perceived knowledge. The age range of eighteen to thirty-nine perceive themselves to have a much greater knowledge of functional safety and machinery safety then the age groups above forty.

The majority of respondents in this age group work in the DSEAR and central teams which could explain this, however, the spread is throughout several manufacturing areas, there may be a reason for this. Functional safety especially is the newest focus under the process safety umbrella. The need for process safety and completing the HAZOPs and LOPAs is well established, but the functionality and design of the solutions to reduce risks to ALARP has only really been pushed within industry in the last ten years. Hence functional safety are terms used more frequently in chemical and process industries; academic institutes, industrial apprenticeships, and other alike industry than would have been historically.

5.1.3 Question 2

The second question asked was to gain an understanding of the awareness of people of functional safety management planning, figure 16 shows the results of this question.

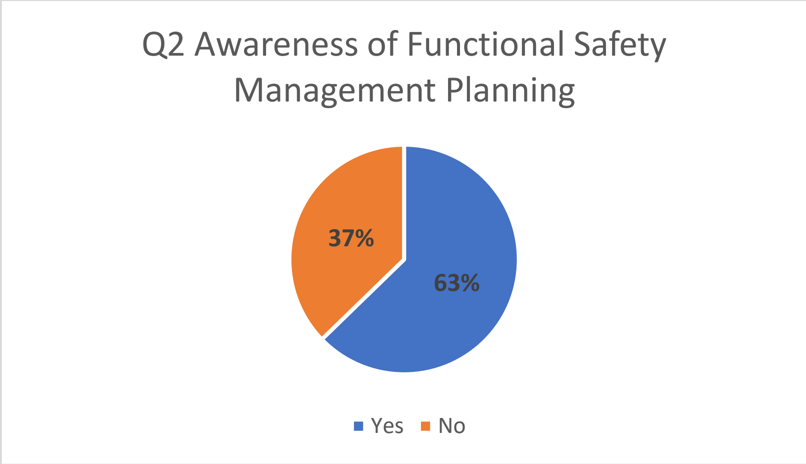


Figure 16: Awareness of functional safety management planning

The analysis shows that thirty-two (63%) of respondents are aware of functional safety management planning. This ties up with the results from question one where thirty-five where sixty-eight percent of respondents said they had basic or better knowledge of Functional safety. On the contrary the percentage of respondents aware of functional safety management planning could be attributed to the words, safety, management and planning which are words used routinely throughout the business. This still means that thirty seven percent of people involved in functional safety are not aware of functional safety management planning, which further strengthens the need of a checklist identifying the planning stages along with further awareness training is required.

5.1.4 Question 3

The third question looked at each stage within the safety life cycle and who is responsible for each stage. Figures 17, 18 and 19 show the responses to this question.

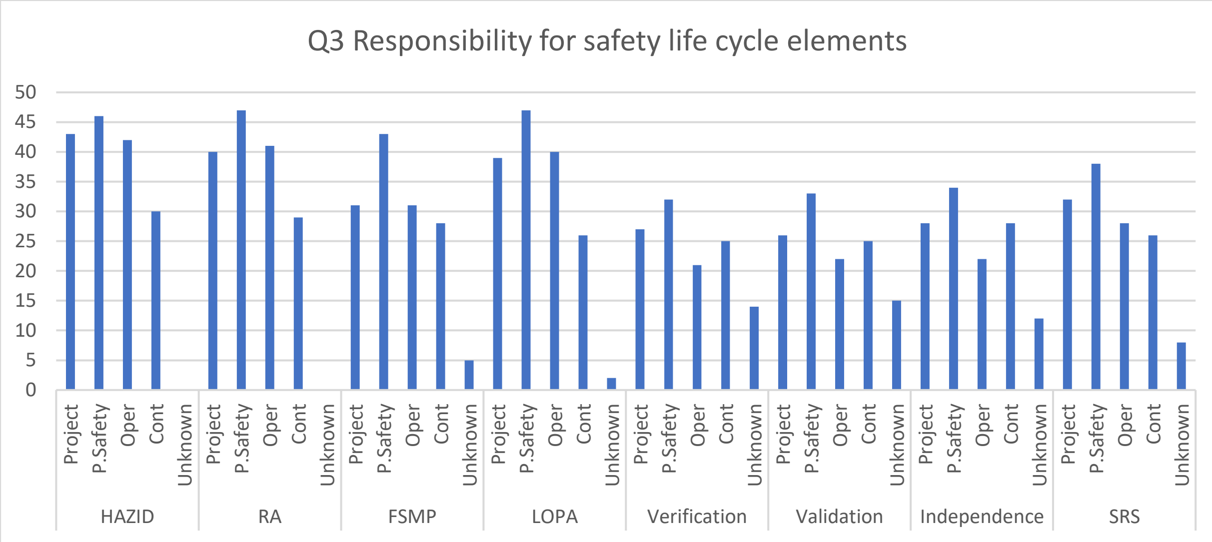


Figure 17: Responsibility for each element of the safety life cycle

The safety lifecycle elements selected in figure 17 all identify the process safety department as being the responsible department for these tasks. This could be due to these tasks are not tasks completed on a daily basis within a department but are typical tasks completed in a process safety review or in a project for new items of plant that have process safety implications. Whilst the process safety team have a more holistic understanding of the process safety regulations and regularly function as a conscience for the specific works area, the in-depth process knowledge and plant safety implications remains with the operational teams.

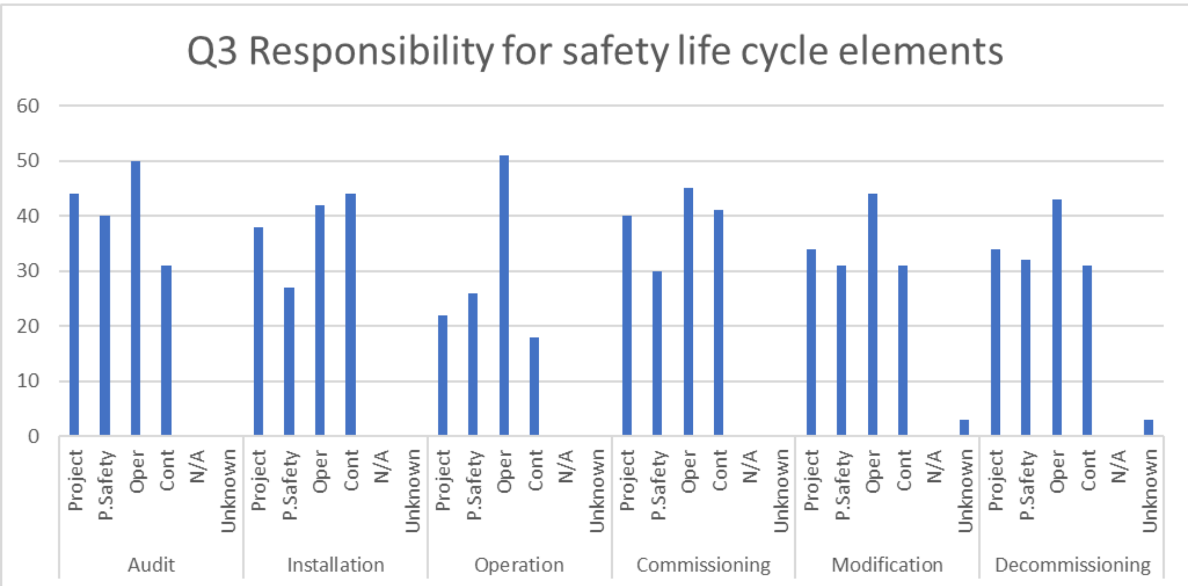


Figure 18: Responsibility for each element of the safety life cycle

In contrast, the safety life cycle elements in figure 18 all show the operational team as being the responsible department for these tasks. This may well be influenced as these tasks are typically tasks completed on a daily basis within a works area. The operation of plant clearly stood out as expected as being the responsibility of the operations team. The only areas where operations were not clearly the responsible areas are Installation and commissioning. These results are skewed as Tata has a heavy reliance on contract partners to complete the majority of maintenance tasks and new installations as contractors have the labour and skills to flex to demands both internally within tata and the external industries they serve.

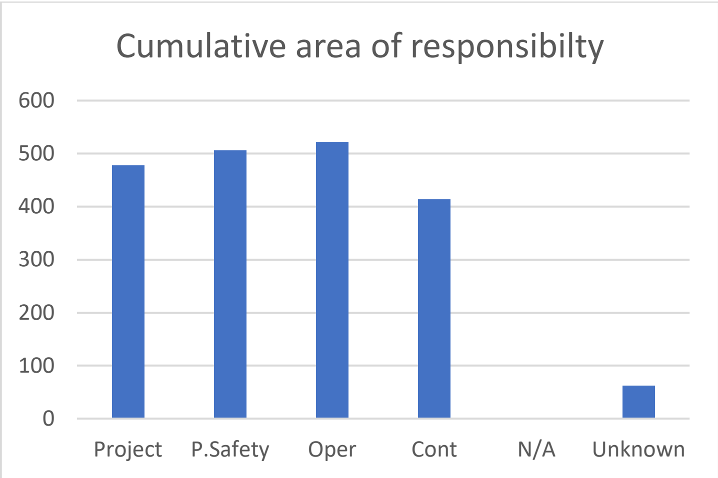


Figure 19: Cumulative area of responsibility

Figures 17 and 18 analysed the functional safety life cycle elements for responsibility individually, figure 19 shows the cumulative score for all fourteen elements combined. The operations department is identified as the overall responsible department. In total 714 is the maximum any department could score (51 respondents x 14 life cycle elements) 73% of respondents picked operations as the responsible department which is expected. Process safety were a close second, this can be apportioned to several life cycle elements not being daily tasks for operations and as such viewed by manufacturing areas as being owned by the process safety department.

5.1.5 Question 4

The fourth question aimed to identify how each respondent ranked the importance of each element within the safety lifecycle and figure 20, tables 6 and 7 show the responses to this question.

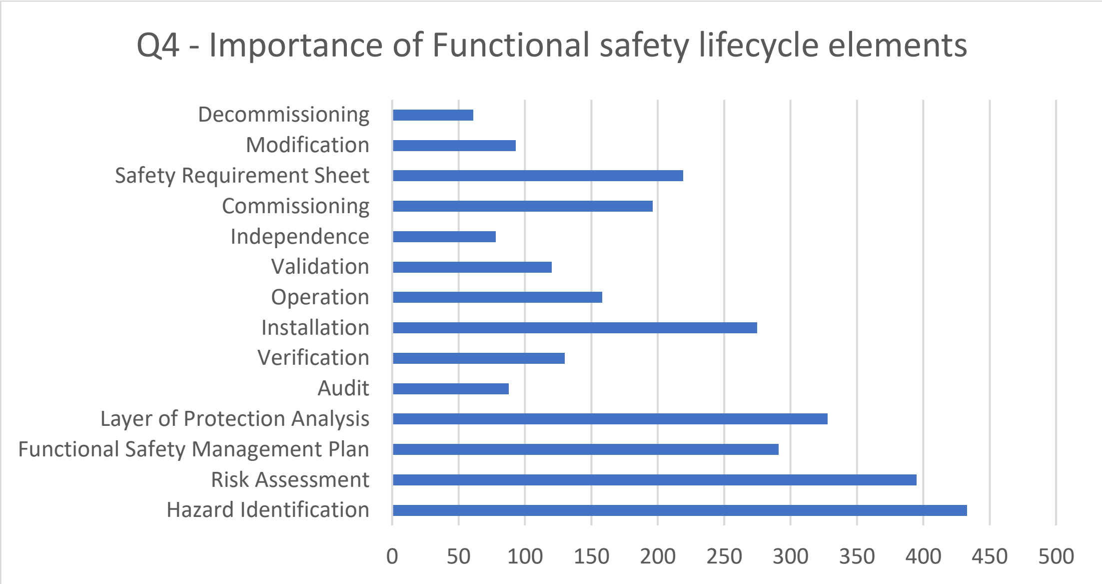


Figure 20: The importance of the life cycle elements

Overall Position		Count
1	Hazard Identification	**433**
2	Risk Assessment	**395**
3	Layer Of Protection Analysis	**328**
4	Functional Safety Management Planning	**291**
5	Installation	**275**
6	Safety Requirement Specification	**219**
7	Commissioning	**196**
8	Operation	**158**
9	Verification	**130**
10	Validation	**120**

Table 6: Overall position by count

Overall Position		Weighted Average
1	Hazard Identification	**8.49**
2	Risk Assessment	**7.47**
3	Layer Of Protection Analysis	**6.43**
4	Functional Safety Management Planning	**5.71**
5	Installation	**5.39**
6	Safety Requirement Specification	**4.29**
7	Commissioning	**3.84**
8	Operation	**3.10**
9	Verification	**2.53**
10	Validation	**2.35**

Table 7: Overall position by weighted average

The literature research suggests that the functional safety management plan should be created at the onset of a process safety project or modification, and this would intimate that it is the most crucial element within the lifecycle. Tata, however, follow a slightly different approach, where a hazard study one, two and three; the associated risk assessment and layer of protection analysis are completed and only where the risk remains intolerable, and an automated electrical engineering solution is required to close the gap does functional safety come into use.

The Tata approach would explain the reasoning behind the top four in the importance list, the remainder of the list is not as the literature would expect and this randomness does not change when ranked by count (table 6) or weighted average (table 7). When combined with the lack of perceived knowledge; the lack of awareness of functional safety management planning and the perception many elements are the responsibility of other departments would explain this random order. This suggests that a checklist identifying the order the lifecycle elements should be completed in, would be beneficial.

Table 8 shows the top ten by age, there is very little difference the age groups and variation to the overall position. Table 9, then shows the top ten by high level distribution area, again there is very little variation in the overall position by area compared to the overall.

	18 to 29		30 to 39		40 to 49		50+	
1	Hazard Identification	64	Hazard Identification	91	Hazard Identification	134	Hazard Identification	144
2	Risk Assessment	58	Risk Assessment	81	Risk Assessment	119	Risk Assessment	137
3	Layer Of Protection Analysis	47	Layer Of Protection Analysis	65	Layer Of Protection Analysis	101	Layer Of Protection Analysis	115
4	Functional Safety Management Planning	45	Installation	57	Installation	88	Functional Safety Management Planning	107
5	Installation	42	Functional Safety Management Planning	56	Functional Safety Management Planning	83	Safety Requirement Specification	91
6	Safety Requirement Specification	31	Commissioning	45	Safety Requirement Specification	71	Installation	88
7	Operation	25	Operation	40	Commissioning	70	Commissioning	57
8	Commissioning	24	Safety Requirement Specification	26	Operation	45	Verification	55
9	Verification	23	Modification	22	Validation	42	Operation	48
10	Validation	22	Verification	17	Verification	35	Validation	47

Table 8: Top ten by age group

	1		2		3	
1	Hazard Identification	130	Hazard Identification	130	Hazard Identification	110
2	Installation	129	Installation	129	Risk Assessment	99
3	Risk Assessment	122	Risk Assessment	122	Layer Of Protection Analysis	75
4	Commissioning	112	Commissioning	112	Functional Safety Management Planning	65
5	Layer Of Protection Analysis	99	Layer Of Protection Analysis	99	Installation	59
6	Safety Requirement Specification	91	Safety Requirement Specification	91	Operation	37
7	Operation	88	Operation	88	Verification	36
8	Functional Safety Management Planning	78	Functional Safety Management Planning	78	Audit	35
9	Modification	55	Modification	55	Safety Requirement Specification	35
10	Validation	36	Validation	36	Commissioning	32

Table 9: Top ten by high level distribution area

5.1.6 Question 5a

The fifth question asked the respondents to explain why they chose each element in their top three, these answers were totally free text. As each respondent potentially had a different top three, the answers for question five sections a, b and c are based on the overall ranking identified in question four.

The answers to position one element hazard identification are collated into a word cloud, see figure 21, to identify the most frequently occurring word, the count for the top ten most frequently used words can be seen in Table 10.

Figure 21: Word cloud of most frequent words used to describe hazard identification.

As expected, identification and hazards account for 43% of the total number of words used to explain hazard identification, in total ninety-one different words were used in the responses, suggesting the term is consistently understood.

Word	Frequency
identify	20
hazards	20
plant	5

safety	5
correctly	4
equipment	4
essential	4
work	3
installed	3
right	3

Table 10: Top ten words used for hazard identification.

The top phrase used in the responses with eleven results is “identify hazards” this is followed with five responses to “identify all hazards.” The majority of the responses to this question were noticeably short statements basically copying the life cycle element chosen.

Forty respondents chose hazard identification in their top three and there were some good individual descriptions that are very similar to the OSHA (2023) definition, these include :-

Respondent 12 – “HAZID confirms all hazards identified and actioned”.
Respondent 19 – “Without understanding hazards things will be missed”.
Respondent 28 – “Identify hazards that can cause harm”.

OSHA (2023) define hazard identification as
“*Collect and review information about the hazards present or likely to be present in the workplace.”*

Table 11 shows the age group and high-level distribution area for the respondents with the most accurate answer. As can be seen, there is no correlation between distribution areas, but the age group suggest the 18-29 age group provide the more detailed answer. This could be due to these people are fresh and recently trained, hence the textbook answer is at the forefront of their minds.

Respondent	Age Group	Distribution Area
12	18-29	2
19	18-29	1
28	30-39	3

Table 11: Breakdown of respondents age group and distribution area

5.1.7 Question 5b

The answers to position two element risk assessment are also collated into a word cloud, see figure 22, to identify the most frequently occurring word, the count for the top ten most frequently used words can be seen in Table 12.

Figure 22: Word cloud of most frequent words used to describe risk assessment.

As expected, risks accounts for 24% of the total number of words used to explain risk assessment in total eighty-four different words were used in the responses, suggesting the term is consistently understood.

Word	Frequency
risks	20
hazards	10

reduce	10
identify	9
reduction	8
risk	7
correctly	6
measures	5
RA	5
identifies	5

Table 12: Top ten words used for risk assessment.

There was no common theme evolved to describe risk assessment but twenty-four (47%) of the responses were around identifying, assessing, and reducing risks.

Thirty-Nine respondents chose risk assessment in their top three and there were some good individual descriptions that are very similar to the CCOHS (2023) definition, these include :-

Respondent 09 – "Correct RA Identifies all potential risks and reduction measures".
Respondent 12 – "Reduce the likelihood of hazard realising harm - reducing risks".
Respondent 42 – "understand and reduce risks to ALARP".

CCOHS (2023) define risk assessment as :-
"A process to decide what measures should be in place to effectively eliminate or control the harm from happening"?

Table 13 shows the age group and high-level distribution area for the respondents with the most accurate answer. As can be seen, there is no correlation between age, but the distribution area suggest that group 2 (Central), subgroup 6 (Process safety) provide the more detailed answer. This could be attributed to the process safety having a better understanding of risk assessment as this is something they live and breathe on a daily basis.

Respondent	Age Group	Distribution Area
9	50+	2 (6)
12	18-29	2 (6)
42	30-39	2 (12)

Table 13: Breakdown of respondents age group and distribution area

5.1.8 Question 5c

The answers to position three element layer of protection analysis are again collated into a word cloud, see figure 23, to identify the most frequently occurring word, the count for the top ten most frequently used words can be seen in Table 14.

Figure 23: Word cloud of most frequent words used to describe layer of protection analysis.

As expected, the words used to explain layer of protection analysis were not as straight forward as the words used to explain hazard identification or risk assessment, in total one hundred and six different words were used in the responses, suggesting the term is not well understood.

Word	Frequency
ALARP	9

risk	9
safety	7
risks	7
LOPA	6
required	6
reduce	6
installed	5
identifies	5
tolerable	5

Table 14: Top ten words used for layer of protection analysis.

There was not a common response to describe layer of protection analysis but fourteen (28%) of the responses were around ALARP and tolerable levels.

Twenty-two respondents chose layer of protection analysis in their top three and thirty-four in the top four. There are some good individual descriptions that are very similar to the Science Direct (2023) definition, these include :-

Respondent 12 – "LOPA ensures all risks are tolerable or ALARP".
Respondent 20 – "LOPA understand the barriers in place to prevent top events occurring".
Respondent 23 – "Identifies the actions required to prevent the hazard causing harm (barriers)"

Science Direct (2023) define layer of protection analysis as :-
"*A method of analysing the likelihood (frequency) of a harmful outcome event based on an initiating event frequency and on the probability of failure of a series of independent layers of protection capable of preventing the harmful outcome*."

Figure 24 shows this in a pictorial manner, where each individual protection layer (IPL) reduces the likelihood of the initiating event resulting in a loss. The more layers of protection the lower the chance of the unsafe outcome, however each layer of protection needs to be fully documented and maintained.

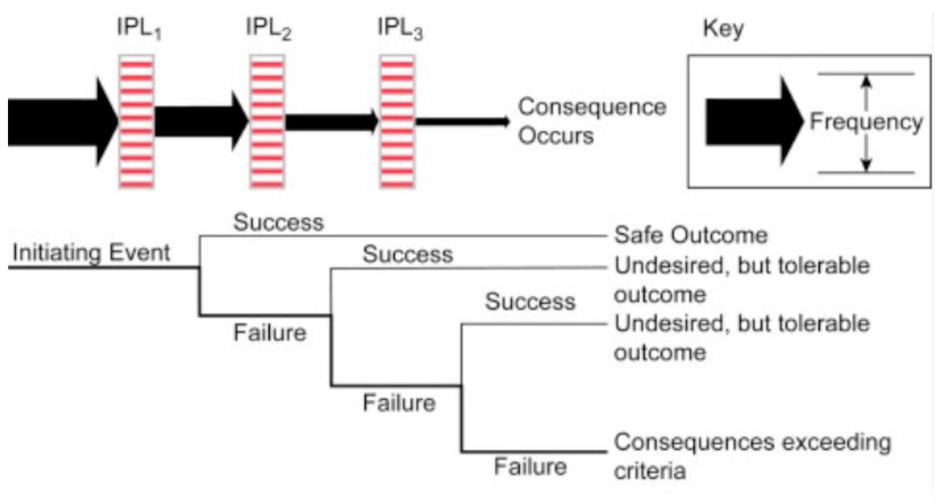


Figure 24: Layer of protection explanation

Table 15 shows the age group and high-level distribution area for the respondents with the most accurate answer. As can be seen, there is no correlation between either age or distribution area. This would suggest that the level of knowledge in the LOPA process although low is even across the site.

Respondent	Age Group	Distribution Area
12	18-29	2
20	40-49	1
23	30-39	3

Table 15: Breakdown of respondents age group and distribution area

A standard checklist document identifying the lifecycle elements and a training matrix would help managers understand the knowledge and competence level of their teams against elements and a gap analysis would identify further training needs.

5.1.9 Question 6

The sixth question asks the respondents to describe a functional safety management plan (FSMP) in their own words and figure 25 and Table 16 show the responses to this question.

Figure 25: Word cloud of most frequent words used to describe functional safety management planning.

As seen in question five the majority of the responses incorporate planning and safety but also included variation. In total one hundred and twenty-five different words were used in the responses, suggesting the term is again not well understood.

Word	Frequency
safety	28
planning	22
functional	15
project	11
stage	11
aspects	10
ensures	9
people	9

right	8
FSP	8

Table 16: Top ten words used for functional safety.

The most common responses to describe functional safety planning included the words, functional, safety and FSP, this accounted for thirty-six (71%) of the responses. There were some good individual descriptions that are very similar to the Exida (2023) definition, these include :-

Respondent 10 – “from concept to grave, FSMP ensures the right people with the right competency are involved at each stage of the process”.
Respondent 13 – “FSMP occurs throughout the process, each step either needs verification or validation and the plan should show who is responsible for each step”.
Respondent 35 – “planning the functional safety elements of a project e.g., LOPA, SRS, FSA & commissioning is done correctly by competent people”.

Exida (2023) define a functional safety management plan as :-
“A written functional safety management plan defines the desired path and success metrics to ensure functional safety objectives are met at all stages.”

Table 17 shows the age group and high-level distribution area for the respondents with the most accurate answer. As can be seen, there is both correlation between ages being in the over fifty group and not related but there is a separate correlation between the distribution area suggesting that group 2 (Central), subgroup 6 (Process safety) provide the more detailed answer. The subgroup respondents could be attributed the process safety department having greater exposure to process the functional safety legislation and the functional safety management plan. However, the age group answer contradicts the perceived knowledge in this age group, which could suggest this age group have more knowledge than they admit.

Respondent	Age Group	Distribution Area
10	50+	2 (6)
13	18-29	2 (6)
35	50+	1

Table 17: Breakdown of respondents age group and distribution area

When the results of this question are combined with question 2 it is not surprising people struggle to explain what they are not familiar. As such a standard lifecycle checklist identifying each stage along with further awareness training is required.

5.1.10 Question 7

The seventh question asks the respondents to identify the components that make up competency in their own words and figures 26 and Table 18 show the responses to this question.

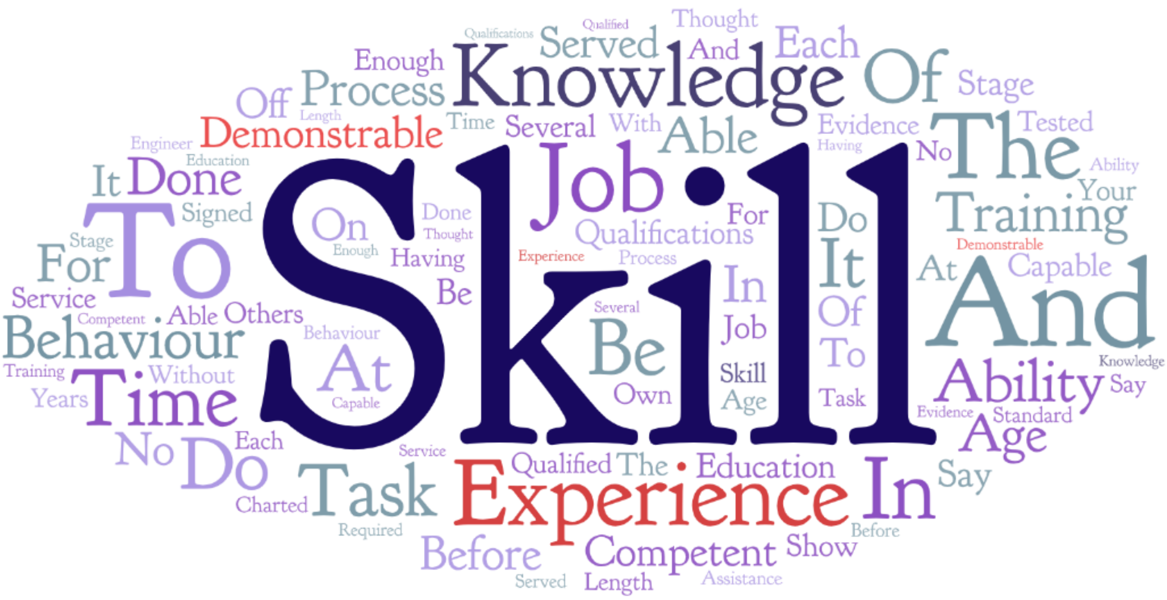


Figure 26: Word cloud of most frequent words used to describe competency.

There were three clear words used the explanation of competency and they included skill, knowledge, and experience. In total only forty-two different words were used in the responses, suggesting that competency is well understood within the business.

Word	Frequency
knowledge	39
skills	35

experience	34
demonstrable	19
behaviour	9
training	7
skill	7
job	4
ability	4
task	3

Table 18: Top ten words used for competency.

The top three words being skills, knowledge and experience accounted for 39 (77%) of the responses. Nineteen (38%) of the respondents added the word demonstrable making the answer rounded by intimating you are more competent if you have demonstrable skills, knowledge, and experience than without it. There were some good individual descriptions that are very similar to the White (1959) et al definition, these include :-

Respondent 10 – "Skill, knowledge experience. Demonstrable for the task"
Respondent 13 – "Demonstrable skills, knowledge and experience in each stage of the process"
Respondent 35 – "Demonstrable i.e., assessed and signed off skills, knowledge and experience".

White (1959) define competency as :-
"*Competence is the combination of practical & theoretical knowledge; cognitive skills and behaviours used to perform a specific role."*

Table 19 shows the age group and high-level distribution area for the respondents with the most accurate answer. As can be seen, there is both correlation between ages being in the over fifty group and there is a separate correlation between the distribution area suggesting that group 2 (Central), subgroup 6 (Process safety) provide the more detailed answer. The distribution area could be attributed the process safety department having greater exposure to competence and demonstrable competence whereas the age group responses are from years of internal training material describing competence as a mix of demonstrable, skills, knowledge, and behaviours.

Respondent	Age Group	Distribution Area
10	50+	2 (6)
13	18-29	2 (6)
35	50+	1

Table 19: Breakdown of respondents age group and distribution area

5.1.11 Question 8

The eighth question asks the respondents to describe independence in relation to functional safety in their own words and figure 27 and table 20 show the responses to this question.

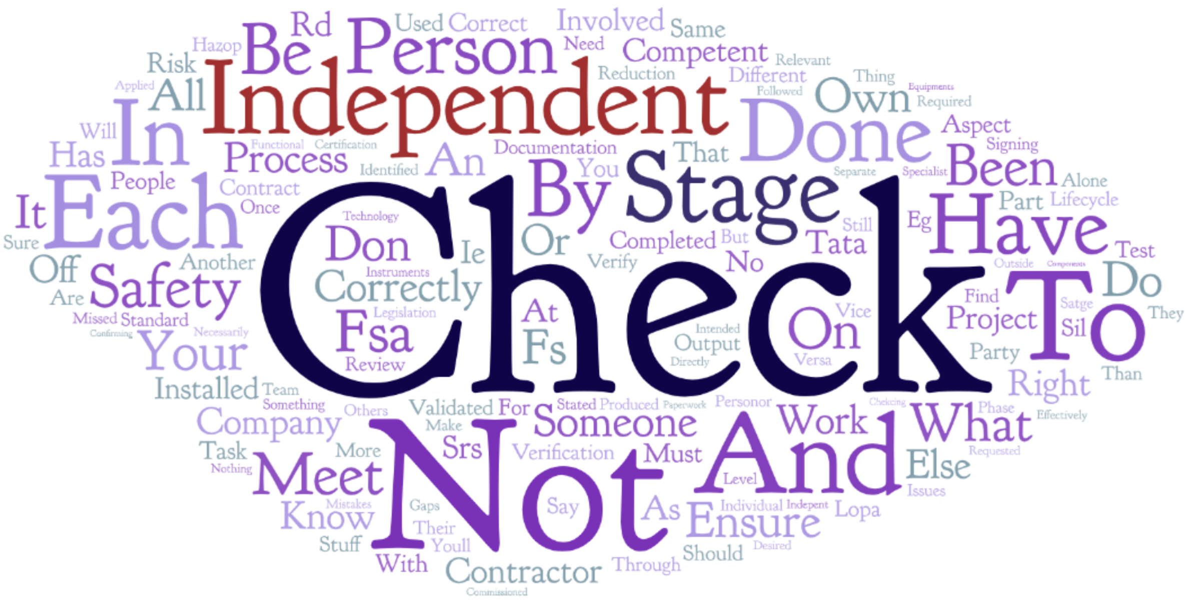


Figure 27: Word cloud of most frequent words used to describe independence in relation to functional safety.

With the exception of the word "check," there was no one clear word or common thread used in the descriptions of independence in relation to functional safety. Even though, in total one hundred and twenty-four different words were used in the responses, the responses are not aligned to each other, confirming functional safety is not understood.

Word	Frequency
checking	21
done	13
independent	12
stage	12
person	11
safety	10
correctly	9
someone	9
competent	8
company	7

Table 20: Top ten words used for independence in relation to functional safety.

The main word used "check" accounted for twenty-one (41%) of all responses. Outside this each explanation was independent with limited words, however, there were some good individual descriptions that are very similar to the Method (2023a) definition, these include :-

Respondent 06 – "Independent person, i.e., independent to project checks each stage is completed and meets the risk reduction identified and relevant legislation".
Respondent 24 – "A competent contracting company outside of the process checking through all documentation produced to ensure they are right and meet the standards".
Respondent 35 – "Someone not involved at each stage of the project checking each phase is done correctly and by a competent person".

Method (2023a) define independence as :-
"*Independence is an essential requirement. The verifier should be conducting a "cold eyes" review on a document that is entirely new to them. The competence to conduct verification is normally the same as that required to do the work itself*."

Table 21 shows the age group and high-level distribution area for the respondents with the most accurate answer. As can be seen, there is no correlation between the respondents ages but there is correlation between the distribution area suggesting that group 3 (other manufacturing areas) provides the most detailed answers, although there is no correlation between the subgroups.

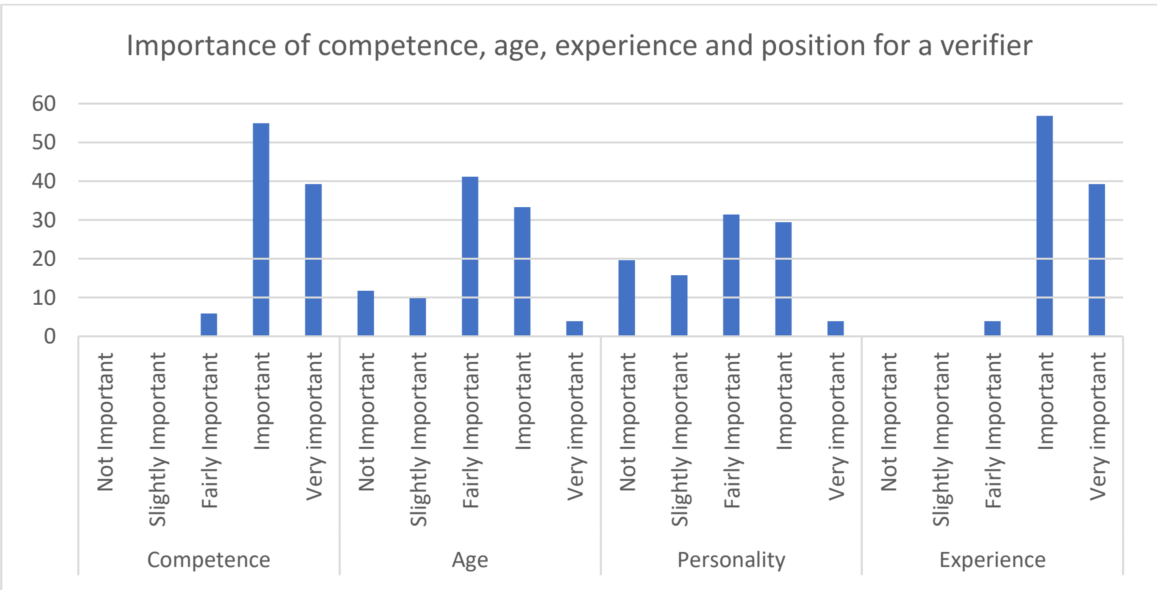
Respondent	Age Group	Distribution Area
6	18-29	3 (9)
24	40-49	3 (2)
35	50+	1

Table 21: Breakdown of respondents age group and distribution area

The inability to explain independence was expected given the level of knowledge around the topic already identified, further strengthening the need for a standard checklist and additional training.

5.1.12 Question 9

The ninth question asks the respondents to rank the priorities for each trait for a person conducting verification and figures 28, 29 and table 22 show the responses to this question.



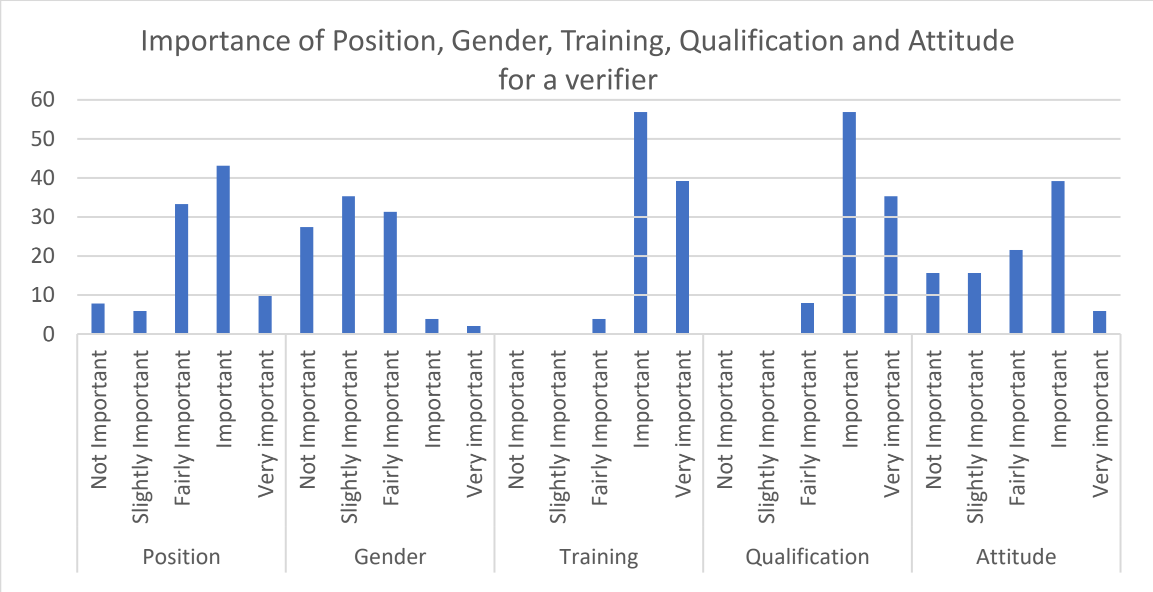
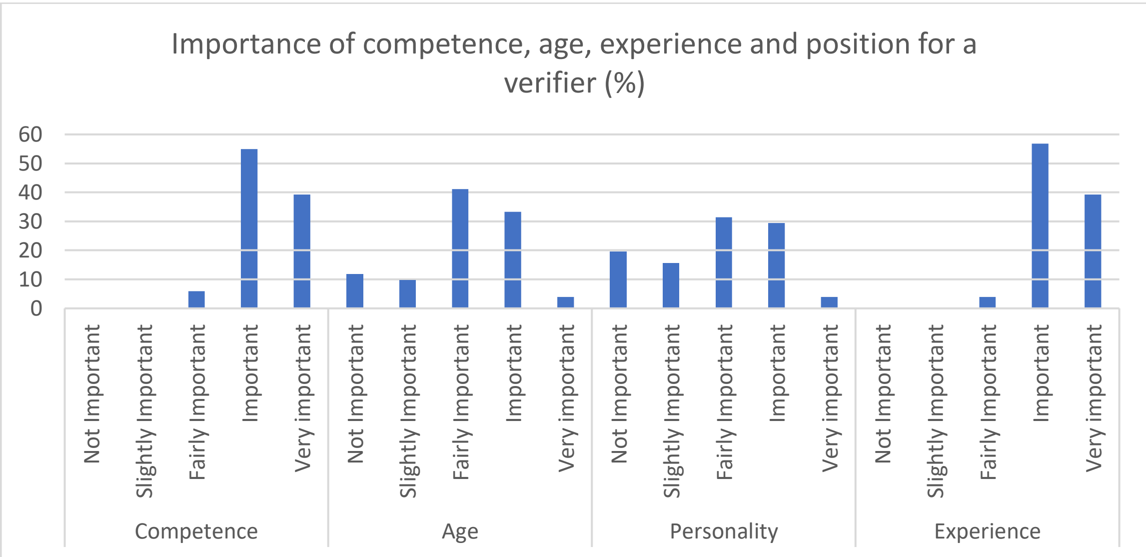


Figure 28: Count of importance of various traits for a person conducting verification.



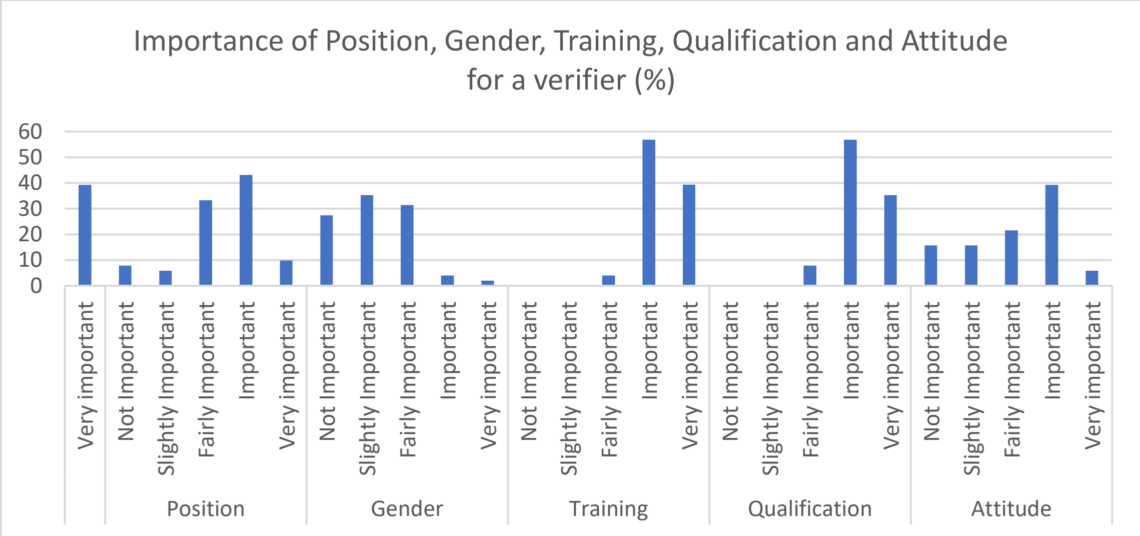


Figure 29: Percentage of importance of various traits for a person conducting verification.

Figures 28 and 29 clearly show that competence; experience, training and qualifications are the most important traits for the person conducting verification. These traits, with the addition of project independence are exactly what the functional safety regulations require to be defined in the functional safety management plan before commencing any work.

1	Training	222
2	Experience	222
3	Competence	221
4	Qualification	218
5	Position	174
6	Age	157
7	Person	144
8	Attitude	153
9	Gender	111

Table 22: Verification traits ranked based on total score.

Table 22 confirms the importance identified of the top four traits in relation to the person conducting verification.

Figure 30 and table 23 show a significant difference in means of personality, gender, and attitude in high level group 3 (Other manufacturing areas) in relation to the other groups and statistical average.

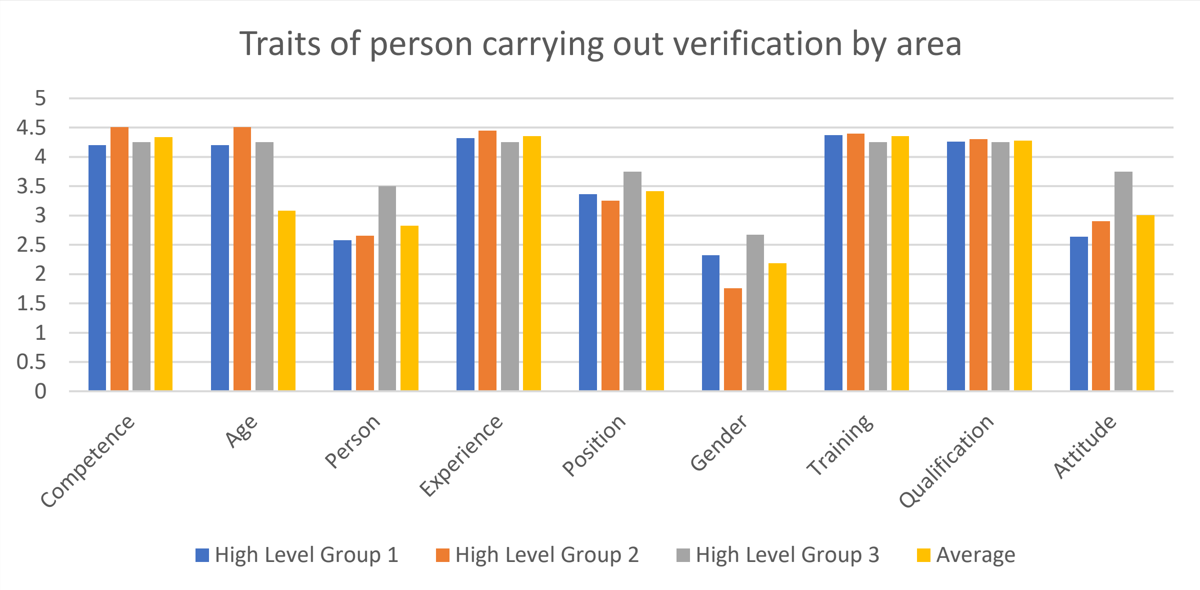


Figure 30: Verification traits by high level area

Breakdown by work area									
Distribution Group	**Competence**	**Age**	**Person**	**Experience**	**Position**	**Gender**	**Training**	**Qualification**	**Attitude**
1	4.2	4.2	2.58	4.32	3.36	2.32	4.37	4.26	2.63
2	4.5	4.5	2.65	4.45	3.25	1.75	4.4	4.3	2.9
3	4.25	4.25	3.5	4.25	3.75	2.67	4.25	4.25	3.75
Average	**4.33**	**3.08**	**2.82**	**4.35**	**3.41**	**2.18**	**4.35**	**4.27**	**3**

Table 23: Breakdown of verification traits by high level area

Figure 31 shows the Minitab analysis of attitude, whist figure 32 shows the detailed analysis where subgroup 10 (HRP) has an average of four. This could be attributed to a specific person in this area who is influential or enthusiastic about functional safety.

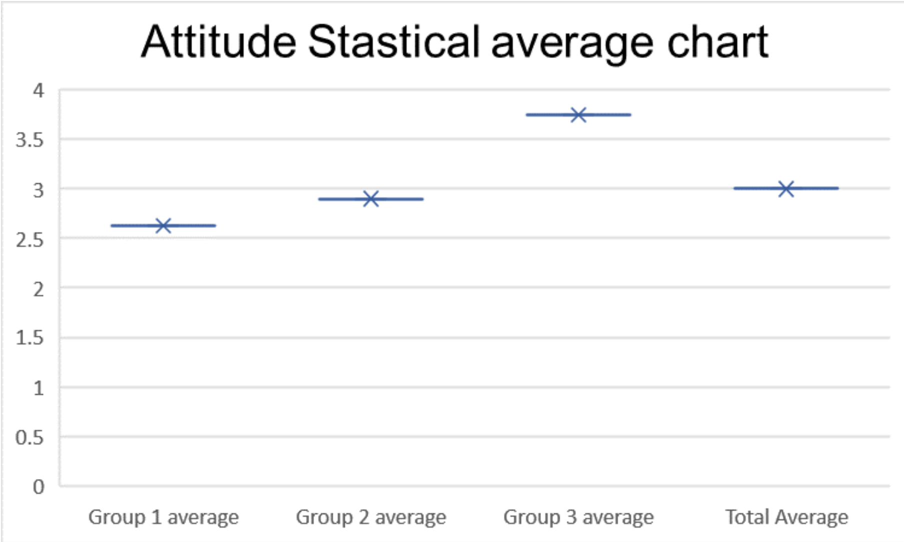


Figure 31: Minitab statistical average chart for attitude

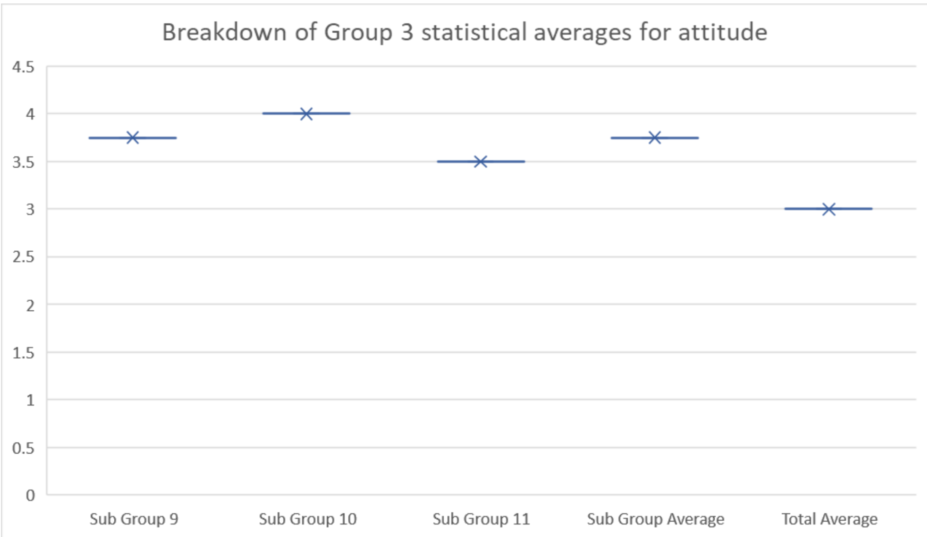


Figure 32: Minitab breakdown of group 3 statistical averages for attitude

Subgroup 10 (HRP) is also the contributory factor in the raised mean for both personality and gender. This could also back up the hypothesis that there is an influential person within functional safety at hot rolled products or that the respondents within HRP were distracted when completing the questionnaire.

Figure 33 and table 24 shows how the traits of the person conducting verification by the mean of each age group shows no significant statistical difference. There are very minor inconsistencies where the 18 – 29 age group have a slightly higher mean than the others in all areas, this could be attributed to them having only recently having gone through training, competence and qualifications so place a bigger value on these aspects. Position may again be perceived as being more important as the persons teaching and mentoring these would naturally be of a higher position within the organisation.

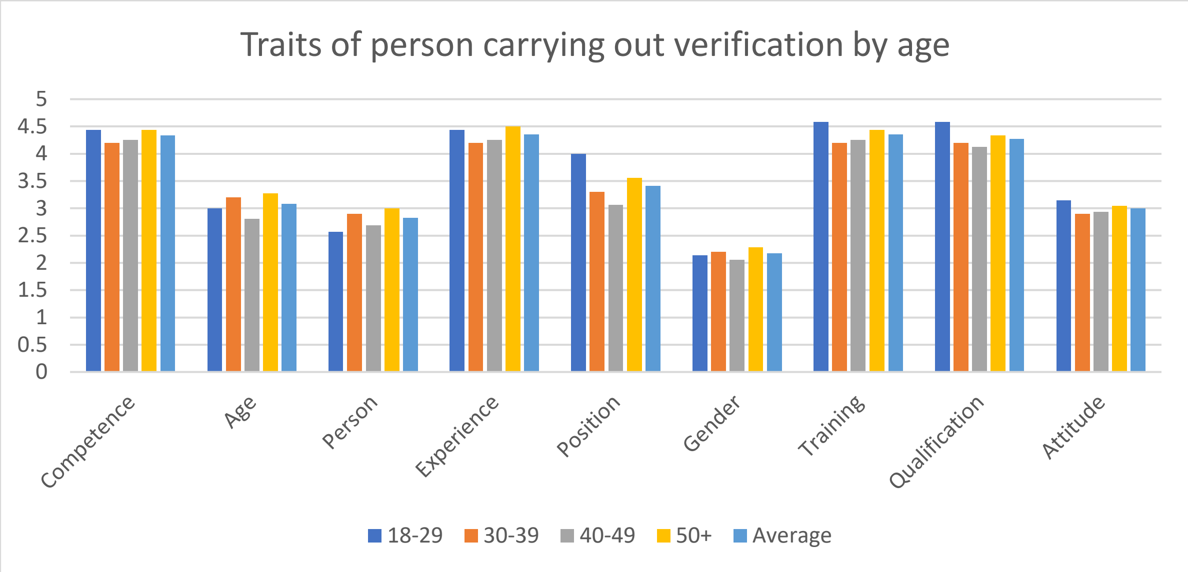


Figure 33: Verification traits by age

Breakdown by age									
Age Group	**Comp**	**Age**	**Person**	**Experience**	**Position**	**Gender**	**Train**	**Qual**	**Attitude**
18 to 29	4.43	3	2.57	4.43	4	2.14	4.58	4.58	3.14
30 to 39	4.2	3.2	2.9	4.2	3.3	2.2	4.2	4.2	2.9
40 to 49	4.25	2.81	2.69	4.25	3.06	2.06	4.25	4.12	2.94
50+	4.44	3.28	3	4.5	3.55	2.28	4.44	4.33	3.05
Average	**4.33**	**3.08**	**2.82**	**4.35**	**3.41**	**2.18**	**4.35**	**4.27**	**3**

Table 24: Breakdown of verification traits by age

Whilst the traits required of a person conducting verification were as the literature suggests, the Author's reflection, believes this may have identified generic traits for a person carrying out any activity as it has already been identified that individuals are not familiar with the functional safety lifecycle elements and verification would not be expected to differ in this.

5.1.13 Question 10

The tenth question asks the respondents whether a check list indicating the key requirements and competencies for each stage of the life cycle would be useful and figure 34 show the response to this question.

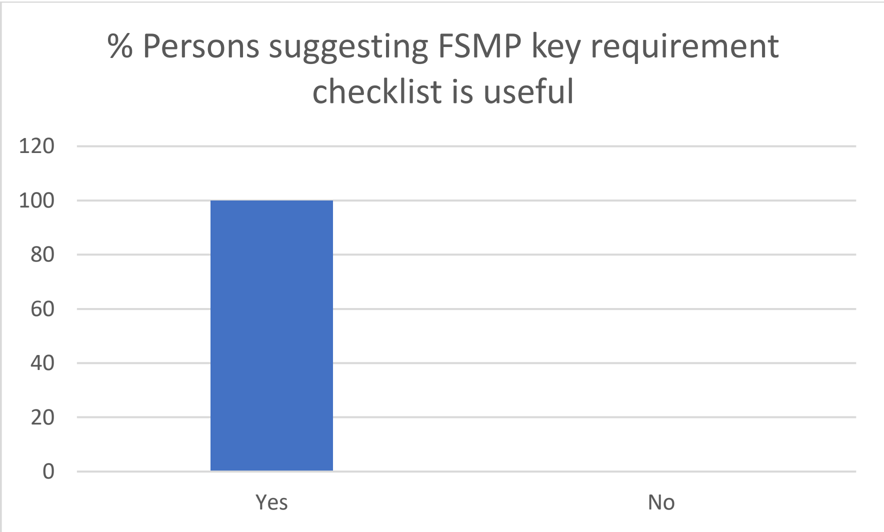


Figure 34: Checklist requirement for functional safety management planning

The analysis shows that one hundred percent of the sampled population believe a key requirement checklist would be useful in developing and managing a functional safety management plan. Based on the results of the previous questions one through to nine, a high percentage in favour of a checklist was expected by the Author.

5.2 Interview 1 analysis

The initial interview took place with the Tata steel UK process safety manager, in this interview several questions were asked to gain their perception on the existing functional safety policy, its implementation and issued identified from the research and the completed project using the existing policy.

The TSUK process safety manager was not totally surprised with the perceived gaps in individuals knowledge of functional safety as this is still a relatively new process and has not been fully rolled out throughout to all levels and individuals throughout the business. It was commented that the training completed should have covered the majority of the people within the sample population especially within the central process safety team; local manufacturing area process safety teams and manufacturing area PCA engineers as these have all been trained and signed off as competent and many are the local champions i.e. the persons responsible for SILs, proof testing and documentation in their respective areas. The need for additional training and a potential second rollout of functional safety would be beneficial.

The process safety manager himself is not an advocate of the "use of proformas" when conducting any form of work, especially around process safety as there is always a risk that outdated documents or edited documents are used which result in omissions or incorrect decisions made in safety critical documentation. Controlling documentation downloaded onto individual's computer an almost impossible task and as such the current regulations should always be referenced. This in in contrast to the current live functional safety policy in operation, which includes numerous proformas for the individual aspects such as hazard study 1 – 5; functional safety assessments 1 – 4; HAZOP's and LOPA's.

The process safety manager is also concerned that proformas dilute competence as people become reliant on proformas and do not challenge, refer to current legislation or think outside the box. It was commented that the functional safety policy is reviewed and updated every three years and any major change in legislation should also trigger a policy review or update.

The Author believes the questionnaire results show there is a need for a checklist and there is a simple solution to managing this by ensuring revision control of the checklist documentation; storage within a simplistic document management system, as seen in figure 35 and having competent people would overcome these concerns.

The current TSUK functional safety policy was written after the process safety policy was developed and included representatives from around the business. When the competencies of the individuals involved in writing the policy and whether the final document had been checked by an external competent third party, the answer was vague at best. The process safety manager concluded that within the last twelve months TSUK has utilised a third-party expert company to assist in reviewing the policy and make suggestions to improve its content.

The process safety manager believes that the existing functional safety management suite located in the functional safety document management suite (DMS) see figure 35 is comprehensive and covers all areas of functional safety. Although it was pointed out that the majority of the documentation had been created before incumbent was in role and eventually agreed these documents need review as there were several areas where existing documentation did not accurately reflect the current standards, previous documents had been signed off by senior business leaders and that prior to this they had been peer reviewed and signed off by an internal TSUK senior manager.

PE Process and Technolog	DMSQMS-1781328358...	TSUK FSMS 001 01 Competency Assessm...	3.0	01/08/2023
PE Process and Technolog	DMSQMS-1781328358...	TSUK FSMS 001 02 Competency Assessm...	3.0	01/08/2023
PE Process and Technolog	DMSQMS-1781328358...	TSUK FSMS 001 03 Competency Assessm...	3.0	01/08/2023
PE Process and Technolog	DMSQMS-1781328358...	TSUK FSMS 001 04 Competency Assessm...	4.0	01/08/2023
PE Process and Technolog	DMSQMS-1781328358...	TSUK FSMS 001 05 Competency Assessm...	3.0	01/08/2023
PE Process and Technolog	DMSQMS-1781328358...	TSUK FSMS 001 06 Competency Assessm...	4.0	09/08/2023
PE Process and Technolog	DMSQMS-1781328358...	TSUK FSMS 001 07 Competency Assessm...	3.0	09/08/2023
PE Process and Technolog	DMSQMS-1781328358...	TSUK FSMS 001 08 Competency Assessm...	3.0	01/08/2023
PE Process and Technolog	DMSQMS-1781328358...	TSUK FSMS 001 Competence.xlsx	4.0	31/03/2023
PE Process and Technolog	DMSQMS-1781328358...	TSUK FSMS 002 Action & Recommendati...	3.0	13/07/2023
PE Process and Technolog	DMSQMS-1781328358...	TSUK FSMS 003 FSA1.docx	2.0	09/03/2023
PE Process and Technolog	DMSQMS-1781328358...	TSUK FSMS 003 FSA2.docx	2.0	10/03/2023
PE Process and Technolog	DMSQMS-1781328358...	TSUK FSMS 003 FSA3.docx	2.0	09/03/2023
PE Process and Technolog	DMSQMS-1781328358...	TSUK FSMS 003 FSA4.docx	2.0	16/03/2023

Figure 35: Extract of documentation in functional safety DMS

A detailed discussion was held around several documents concerning process safety flow; functional safety competence and the functional safety management plan.

The current TSUK process safety flow diagram of which an extract can be seen in figure 36, has functional safety identified as an independent section but this section does not include functional safety management planning. The process safety manager confirmed this was one of many areas of focus and was one of a few learning opportunities to improve and will be included in the next revision but could not confirm when or if this were planned to be completed.

Tata Steel UK Process Safety			TS-UK Health & Safety Management System														
TS-UK Process Safety Elements	Document Management	*Study, Design & Build alignment**	1. Leadership	2. Competence	3. Hazard Identification	4. Compliance Assurance	5. Health & Safety Planning	6. Risk Management	7. Asset Management	8. Management of Change	9. Managing Contractors	10. Operational Control	11. Communication	12. Emergency Preparedness	13. Learning From Events	14. Measuring Performance	15. Audit and Review
Functional Safety																	
PUWER PDCA	Local SharePoint					x			x								
URS	DMS SharePoint	*x*			x			x				x					
SRS	DMS SharePoint	*x*			x			x				x					
FSA 1-3	DMS SharePoint	*x*						x									
FSA 4	DMS SharePoint								x							x	
FSA 5	DMS SharePoint								x	x							
SIF Loop drawings	Cab-i-net	*x*							x								
SIF Proof Tests	SAP	*x*				x			x								

Figure 36: Extract from Tata steel UK process safety flow chart

Competency was the next are that was explored and whilst the competencies of the central process safety team are demonstrable along with those who have been trained and signed off in the local manufacturing areas, a key group of people were clearly missed out i.e., the project managers, team lead and engineers.

The process safety manager views the completion and update of the functional safety management plan as being the responsibility of the manufacturing areas for minor plant changes or in the case of a larger Capex project, the project manager. It was at this point the disconnect between the training and requirements became clear. The process safety manager believes that completing the functional safety management plan after the LOPA has been completed is the right time as it at this point the necessity to implement additional protection is confirmed and the competencies required can then be identified and put in place. The risks of completing the preliminary stages of the process safety life cycle e.g., HS1-3 and the LOPA was low as the business already have a process in place for this, with competent leads; competent people involved and a sign off process. Whilst it was agreed that that after the LOPA was the right place for Tata, concerns were expressed that competence should be documented for the initial stages of the process safety lifecycle and a standardised checklist would be a means of achieving this.

The importance of the functional safety management plan was discussed and although not explicitly stated it was inferred that the plan was not as important as the "physical" stages of the lifecycle and a project could be equally successful irrespective if the functional safety plan was completed or not such as the research project identified. Whilst this project was successful, the lack of the functional safety management plan led to numerous delays, additional costs in rework and redesign and loss of good will between parties.

Several existing documents within the process safety lifecycle were shown to the process safety manager, they are the verification plan as per table 25 and the SRS table 26 and a discussion was held around both documents.

The existing verification plan requirement document was found the be created and live within the DMS but on drilling down was found lacking in relation to the standard and none of the components under the main heading had been completed even as a guide for the end user, thus reinforcing the need for a single standard checklist document that identifies who, what, when and competence level needed for each stage.

TATA STEEL

Procedure

User Group PE Process and Technology Engineering

Process: Empty Document Title: DMS EN Procedure Template

Published date: 05.05.2022 Version: 1.0 Document Owner: PE Functional Safety SC: No

Activity – Verification Item Identification	Measures/Techniques to be used	Persons Responsible	Inputs	Outputs	When	Non Conformance Requirements	Non Conformance Resolution

Table 25: TSUK process safety verification plan

The existing SRS evidence checklist was again live within the DMS and on drilling into the document the question set was incredibly detailed but lacked any mention of the competency of the person providing the evidence or the "checker" doing the verification.

Check Ref.	IEC 61511 Clause	Requirement	Evidence	Comments
SRS01	19 (Various)	Is the SRS Formally correct (Title, author, verifier, ID Number, Status, Revision Number, Dat, Table of contents, Revision log, list of abbreviations, references		
SRS02	10.3.2 a	Is each SIF described ? Using S.L.A.T.S		
SRS03	8.2.3 19.2.5	Are all requirements uniquely identified ?		
SRS04	8.2.3 19.2.5	Are the requirements traceable ?		
SRS05	10.2	Does the SRS correctly describe the requirements as per the H&RA ?		
SRS06	10.3.2 f	Are the assumed sources of demand and the demand rate expected for each SIF		
SRS07	10.3.2 d 10.3.2 l	Does each SIF have a safe state defined ?		
SRS08	10.3.2 o	Is the SIF defined as energised or de-energised to trip ?		
SRS09	10.3.2 g 10.3.2 h	Does each SIF have requirements for proof testing defined ?		
SRS10	10.3.2 y	Does each SIF have a MTTR defined ?		
SRS11	10.3.2 i	Does each SIF have the response time defined ?		

Table 26: TSUK process safety SRS evidence sheet

The next discussion was around the use of the functional safety management plan around site. It was identified that only two projects completed within the last three years needed functional safety considerations, prior to this no projects had functional safety completed up front and both FSA Stage 4 and 5 were done retrospectively.

The process safety manager had not been involved in a full functional safety life cycle project in TSUK, the case study project is the first project that has properly adopted this approach from the outset. Several findings from the case study analysis were discussed in detail and eventually agreed that the right people were not involved at the onset and agreed that if the competencies had been in place, then the update of the plan would have been better managed by the project team.

This then led to the several questions about where the central process safety team sit in this process and agree, they are a separate entity and should be the conscience of the project team or manufacturing area, as a conscience they have prodded the project team to keep the documentation updated and the competency discrepancy should have been flagged at this point. Then the responsibility of updating the management plan should have been taken away from them until trained and deemed competent.

The project manager was asked to arrange the life cycle components in their order of importance. Going through the process in order, the process safety manager missed out FSMP from their top ten aspect of the functional safety lifecycle. Their list was HAZOP; RA; LOPA; SRS; verification; installation; commissioning; validation; independence and operation. On questioning their belief is that the FSMP is completed at each stage i.e., at the start of the HAZOP you identify the competence and input/output documents and then repeat the LOPA etc, when questioned what if the right competency is not available the response is that the session would be cancelled and rearranged.

The process safety manager finally agreed that once the third-party review of the policy was completed an internal working group needs setting up to review documentation on a regular basis and the implementation of a single checklist document identifying each phase the documentation and competence required could be useful.

5.3 Case study analysis

The case study analysis of the functional safety documents 70057733-56-FSP-001 (functional safety management plan) and 70057733-56-FSP-002 (functional safety management plan schedule) was completed as a desktop exercise with the project manager (PM) and the lead engineer.

It was identified during analysis that both documents 70057733-56-FSP-001 and 002 had only been partially completed. The documents were written by an independent company prior to essential documentation being created i.e., neither LOPA or SRS had been completed and would appear that the supplied documentation is more of a standard high level FSMP that could be used on any project and would need updating as the project evolved. On deeper investigation the requirement and importance of the plan was only understood by the project team after completion of HS3 and LOPA and an internal review of the supplied schematics prior to cold commissioning. Further discussion with one of the regularly used third party contractors regarding the supplied documentation, led to the discovery that the issue was deeper than originally thought. This was the first time that anyone within this project team had been exposed to a project that needed functional safety. The Tata functional safety policy states to start the FSMP after HS3 and LOPA identify the need for further actions to reduce residual risk to tolerable.

The project team in place did not have the competence for conducting functional safety work. Generally, the project teams are not selected on the required competence elements within a project but require the project manager to themselves identify the electrical; mechanical; planning; safety and civil & structural resource requirements at the onset and where a competence deficiency arises, they then request further assistance. There is an assumption that the project manager and initial project team knows everything, as is often the case you do not know, what you do not know.

The project team believed the FSMP was a tick box exercise just to say there was a plan in place and the contents were never reviewed; there was no independent review of the contents, and it had no bearing on the project i.e., it was a 100% stand-alone document. The project team commented that had FSMP been prepared properly at the beginning of the project and if reviewed then the lack of competence issues would have been identified in both project team and selected contractor company. This would have saved a lot of time, effort, and expenditure within the project. Document 0001 Section 3.1.1 roles and responsibilities and Section 3.2.1 (See Appendix 9) suggests that document 0002 (See appendix 10) details the roles, responsibilities and competence for each activity of the safety lifecycle for the project.

As a project team there had been no guidance given on how to complete the FSMP although Tata functional safety policy requests one be completed. On review several issues with the Tata documentation were identified and the central process safety team did not have the responses to these questions as this was the first project to use this document in anger. The FSMP does not cover all the elements required and does not identify the minimum competencies requires, this is left to the project engineer and project manager to identify.

Functional safety training for the project team was not received until the end of project, this was conducted by a third party which then introduced further questions as it now became clear the extent of discrepancies in some of the documentation. The project manager is still not trained in functional safety and as such, now solely relies on their own team and the central process safety department for advice as they are unaware of all the requirements. The project manager concluded that functional safety will be added to future tender specification and numerous companies they have spoken to, have replied that they have no competence in functional safety and would outsource this element if required.

Table 27 shows the FSMP produced for the case study project and the competence of the persons involved. For the purpose of GPDR (2018) the names have been removed and replaced with initials. Of the ten project roles identified, only three individuals actually have any functional safety competence and training. Table 28 and

29 then shows the detail behind each element of the safety lifecycle and where issues have been identified.

Persons, Departments and Orgnisations involved in the activities of SIS SLC	Orgnisations involved in the	Project Roles	Assessed Competency Level	Notes
JH	Client	Process Safety Engineer	Practioner	
HR	Client	Process Engineering	Practioner	
CS	Client	Lead Project Engineer	Practioner	
SS	Client	Electrical Project Engineer	Practioner	
TR	SIS Contractor	Design Engineer	Practioner	
JS	SIS Contractor	Site Engineer	Practioner	
LJ	Client	Process Engineer	Practioner	
SM	Client	Plant Electrical Engineer	Practioner	
MB	Client	Plant Electrical Engineer	Practioner	
C&P	Installation Contractor	Installation Contractor	N/A	

Table 27: 7005733-56-FSP-002 - FSMP competency check sheet.

It is presumed that the competence level was assessed using the TSUK FSMS 001 competence document as appendix 11. However, appendix 11 highlights the competencies for each section of the lifecycle. Document 7005733-56-FSP-002 in table 27 only indicate a single competency level. This suggests a checklist would be suitable as it would identify the competencies required at each stage from the onset.

Tasks to be Carried out	Responsibility	Persons Responsible for activities	Inputs/Documentation	Outputs/Evidence	Status	Verifier
Management and Planning Period						
Produce FSP	WSP	TL	Mandatory Control - Functional Safety Management	70057533-56-FSP-0001 Functional Safety Plan	To be verified	RB
			Guidance Note - Functional Safety Management	70057533-56-FSP-0002 FSP Schedule	To be verified	
(1) …sis Period						
HAZOP	Tata	Project team	HAZOP template			
	Tata	Project team	1826-0052-19-01-001 - Basis of Safety			
	Tata	Project team	1826-0052-19-01-003 - HS2			
	Tata	Project team	1826-0052-19-01-002 - Basis of Design			
	Tata	Project team	1826-0052-19-01-004 - Control Philosophy (URS)			
	Tata	Project team	1826-0052-19-01-009 - BPCS Interlocks			
	Tata	Project team	1826-0052-19-01-010 - SIS Interlocks			
	Tata	Project team	10147-18-01-L-001 - Benzole Plant C E Schedule			
	Tata	Project team	10147-18-01-L-002 - Benzole Plant Alarm List			
	Tata	Project team	10147-18-01-R-009 - Benzole Plant Functional Safety Description			
	Tata	Project team	Benzole Plant DSEAR Hazardous Area Classification Zoning Plan			
	Tata	Project team	Benzole Plant DSEAR Hazardous Area Classification Zoning Elevation			
	Tata	Project team	TSE204 MCO Benzole Plant Final HAC Report			
	Tata	Project team	IMC006 HAZOP Studies			
	Tata	Project team	70057533-53-2103 - Benzole Storage Tanks P&ID			
	Tata	Project team	70057533-53-2104 - Benzole and Efflu Pump P&ID			
	Tata	Project team	70057533-53-2105 - Tanker Loading P&ID			
(2)	WSP	Project team	70057533-53-REP-0001 tank venting	70057533-30-HAZ-DOC-0001 Tata Benzole Storage HAZOP Report	Verifed with open actions	JOD
				HAZOP Action Sheets	Verifed with open actions	
1. Level Of Protection Analysis (LOPA) 2. Trip and Interlock Schedule	Tata	Project team	Benzole Storage Bowtie			JH
	Tata	Project team	Tanker Loading Bowtie			JH
	Tata	Project team	LOPA Template Issue 1			
	Tata	Project team	PSG-03.02.56 - LOPA Guide			
	WSP	RC	70057533-53-2103 - Benzole Storage Tanks P&ID (3)	LOPA Worksheet	To be verified	NA
	WSP	RC	70057533-53-2104 - Benzole and Efflu Pump P&ID	LOPA Report	To be verified	NA
	WSP	RC	70057533-53-2105 - Tanker Loading P&ID	Trip & Interlock Schedule	To be verified	NA
	WSP	RC	70057533-30-HAZ-DOC-0001 Tata Benzole Storage HAZOP Report	Updated P&ID	To be verified	NA
	WSP	RC	(4) HAZOP Action Sheets			HR
	WSP	NA				
	WSP	J				
	WSP	JOD				
Issue Supplier Competency Questionnaire to SIS Suppli… Tender (5)	WSP	TL	Supplier Competency Questionnaire			
	Rockwell	TBC		Response to Supplier Competency	To be verified	TL
				Questionnaire	To be verified	TL
Safety Requirement Specifica… (SRS)	WSP	TL	LOPA Worksheet	SRS	To be verified	RB
			LOPA Report	SIL-rated Instrument Datasheets	To be verified	RB
			Trip & Interlock Schedule			
			Updated P&IDs			
Functional Safety Assessment (FSA 1) (6)	WSP	LJ	- FSA 1 Check List	- FSA 1 Report (7)	To be verified	LJ

Table 28: 7005733-56-FSP-002 - Completed FSMP (Analysis section)

1 – WSP not included in competency list.

2 – Activity by WSP, but person responsible is tata project team.

3 – LOPA required to be verified but then marked as Not Applicable.

4 – Responsible person not identified.

5 – Rockwell not on competency list.

6 – Activity by WSP, but person responsible is Tata.

7 – Person responsible is same as verifier.

Tasks to be Carried out	Responsibility	Persons Responsible for activities	Inputs/Documentation	Outputs/Evidence	Status	Verifier
Functional Safety Assessment (FSA 2)	iconsys	JS	- iconsys Functional Design Specification Benzole FDS	- FSA 2 Report	To be assessed	TR
			- iconsys 215029-BPCS-LD - Loop Diagrams			TR
			- iconsys 215029-RCP - Electrical Schematics			TR
Installation and Validation (8)	Iconsys / C&P / Tata	Project team	70057533-56-SPC-0001 E,C&I Installation Specification (by WSP)	- Inspection, Testing and Calibration Certificates - Red-lined drawings (9)	To be verified	CS
FAT/SAT and Pre-commissioning	iconsys	JS	Safety FAT/SAT Plans	- Safety FAT/SAT Reports	To be assessed	TR
				(10)		TR
Commissioning	Tata / Iconsys	Project team		- Acceptance Certificate	To be verified	CS
Functional Safety Assessment (FSA 3)	Tata	JH		- FSA 3 Report	To be assessed	LJ

Table 29: 7005733-56-FSP-002 - Completed FSMP (Realisation section)

8 – C&P not on competence list.

9 – Verifier is not competent.

10 – FAT and SAT verification not including Tata (Activities need splitting up FAT test needs to be completed prior to FSA2).

Tables 28 and 29 are extracts from the actual FSMP Schedule document reviewed at the end of the project, where over 90% of activities are not shown as being verified, even though they were highlighted as needing verification. Document 70057533-56-FSP-001 section 5.2.1. The verification plan confirms the requirements for verification, the verifier and their competence and will be completed in the FSMP schedule. This does not mean that the verification has not been done and may be purely a clerical error, however, should a process safety incident occur the main documents reviewed are the documents the competent authorities would check, these being, the HS3, LOPA, FSMP and FSMP schedule all of which identify functional safety the regulations and the need for competence, verification and validation.

The FSMP schedule review identified beneficial use of document numbers for both the input and output documentation, and this should be seen as best practice, an extra step identified would be to include the documentation revision numbers to ensure the reviewed and verified documents are the final revision.

The review also identified differences between the completed bow tie (appendix 2) and the seven SILs identified in the LOPA, see table 4. The bow tie references pressures and blockages and the relevant SIF loop details have not been completed. The project manager believed the process safety team were managing this and had not identified the discrepancies. The lack of document integration demonstrates the need for a standard checklist.

Thes case study project involved the processing of by products from the coke ovens. This involves storage of Benzole, A highly volatile, flammable substance. The LOPA originally identified eleven safety integrated function (SIF) loops, but after peer review by a third-party instrumentation specialist, duplicate loops were removed and the total number of SIF loops was then reduced to seven.

The system Integration contractor had already been selected and orders placed before HS3 and LOPA was conducted. Functional safety is generally not included as a required competency on tender documents as most new designs already incorporate best practice in system design. However, the current functional safety policy does not identify the actual individual competence, only suggests a competent contractor shall be used, see appendix 12 section 8. The FSMP section 5.3 the validation plan, identifies four areas that need validation they are the Site Acceptance Test (SAT); Installation verification, Pre commissioning and Factory Acceptance Test (FAT). The responsibility for the SAT and FAT validation sits with the SIS supplier, this was not conducted as the SIS supplier did not have this competence and as such only a basic SAT and FAT was completed by the project team, which is not to the standard.

Additional costs to the overall project were in the region of £150k as the documentation supplied prior to cold commissioning of the equipment had missing equipment details, when requested the system integrator initially fought back suggesting the information was not required, then it was not their duty as Tata had specified equipment, cables etc and the entire design had not been completed by themselves. A third-party expert contractor was then employed as an arbitrator between parties, delaying essential paperwork such as loop diagrams and descriptive system document (DSD) to enable the project to move to the cold commissioning stage. Eventually common ground was reached, on supply of the correct documentation it was clear that some instruments or barriers were not suitable for the environment which led to additional delays in time, the system integrate absorbed the additional costs here. Had it not been for the third party neither the tata engineer, procurement or the system integrator knew enough to prove either party wrong. Additional costs were incurred due to incorrect instrumentation purchased and plant modifications required to incorporate the correct instrumentation.

This project attempted to save costs by splitting sections down to its lowest denominator and as such the reliance came upon Tata engineers to be the knowledge experts and integrators between various parties and throughout the duration ended up costing far more than outsourcing the packages in sensible work packages would have cost. An example of this where the system designer was responsible for producing a design only. Once this was produced, they had no further involvement in the project.

As the designer parted on poor terms, communications were difficult at best and any modifications to the design were made and verified by Tata engineers only.

Whilst it would seem common sense in hindsight to keep the designer involved throughout the project, this is not always practical as there can be lengthy delays in capital expenditure approval and installation completion in relation to the completion of the design.

The next section highlights the potential results and how they will be collated to produce a standard proforma. The section further identifies how this research contributes to literature and its use worldwide.

6 Proposed FSMP

From the analysis of the questionnaires, the review of the case study and interviews conducted, the Author has created a proposed functional safety management plan checklist.

The checklist will be a one stop shop where all the relevant details around legality, ownership, resource requirements for both verification and validation; competency of individuals and required input documentation and output documentation is recorded within a single document.

The proposed checklist identifies the following elements :-

- The process safety life cycle activity.
- The relevant clause within IEC 61511-1.
- The task to be conducted.
- The organisation responsible for this activity.
- The person responsible within the organisation.
- The responsible person competency.
- Input documentation required for the task.
- Output documentation from the task.
- The verifier for the task and their competence.
- The level of independence of the verifier.
- The acceptor of the completed documents.
- The validator and verifier of validated tasks (where applicable).

Whilst the list of requirements seems extensive this provides a very quick reference for a project manager to understand their requirements and the competence needed within the direct or support team to successfully complete the project to the correct standard compliant with the current regulations.

Appendix 13 shows the full checklist created by the Author, initially the checklist included all functional safety lifecycle elements inclusive of the hazard study one, two and three, and the LOPA. However, as the Tata policy is not to start the FSMP until the LOPA has been completed, the checkpoint starts at the SRS element of the lifecycle. Tables 30 and 31 show an extract from this document.

SLC Phase	3	10	4	10	5						
SLC Avctivities	Safety Requirement Specifications	Functional Safety Assessment – Stage 1	Design and Engineering	Functional Safety Assessment – Stage 2	Installation, Commissioning and Validation						
Clauses of BS EN 61511-1	Clause 10	5.2.6.1 of Clause 5	Clause 11, 12 & 13	5.2.6.1 of Clause 5	Clause 14 & 15						
Tasks to be Carried out	Safety Requirement Specifications (SRS)	Functional Safety Assessment (FSA 1)	1. Particular attention will be paid to the following	Functional Safety Assessment (FSA 2)	FAT	Installation	Cold commissioning procedure	Cold Commissioning	Proof Test	Hot commissioning procedure	Hot Commissioning / SAT
Orgnisations Responsible for activities	System integrator	Designer	System Integrator	System Integrator	System integrator	EC&I Contractor	Tata	Tata	System integrator	Tata	Tata
Persons Responsible for activities	System integrator Engineer (1)	Tata Process Safety Engineer (1)	System integrator Engineer (1)	System integrator Engineer (1)	System integrator Engineer (1)	Tata projects E,C & I Engineer (1)	Tata projects E,C & I Engineer (1)	Tata projects E,C & I Engineer (1)	System integrator Engineer (1)	Tata projects E,C & I Engineer (1)	Tata projects E,C & I Engineer (1)
Verifier	System integrator Engineer (2)	Tata Process Safety Engineer (2)	System integrator Engineer (2)	System integrator Engineer (2)	System integrator Manager (1)	Tata projects E,C & I Engineer (2)	Tata projects E,C & I Engineer (2)	Tata projects E,C & I Engineer (2)	Tata projects E,C & I Engineer (1)	Tata projects E,C & I Engineer (2)	Tata projects E,C & I Engineer (2)
Independence	Must not have had any inlvolvement with writing the SRS	Must not have been involved in FSA1 assessment	Must not have been involved in the SIS development	Must not have been involved in FSA2 assessment	Not involved in creating FAT procedure	Not involved in the installation process	Not involved in creating procedure	Not involved in commsiioning activities	Not involved in creating procedure	Not involved in creating procedure	Not involved in commsiioning activities
Acceptence	Tata Project Manager (1)	Tata Project Manager (1)	Tata Project Manager (1)	Tata Process safety Engineer (1)	Tata Operations (1)	Tata Project Manager (1)	Tata Project Manager (1)	Tata Operations (1)	Tata Operations (1)	Tata Operations (1)	Tata Operations (1)
Validator	N/A	N/A	N/A	N/A	Tata Project Lead Engineer (1)	N/A	N/A	N/A	N/A	N/A	System integrator Engineer (1)
Verifier (of the validation	N/A	N/A	N/A	N/A	Tata Project Manager (1)	N/A	N/A	N/A	N/A	N/A	System integrator Manager (1)
Verifier Independence	N/A	N/A	N/A	N/A	Not involved in FAT procedure	N/A	N/A	N/A	N/A	N/A	Not involved in the Hot Commissioning / SAT activities

Table 30: Extract from new FSMP checklist front page

Table 30 clearly identifies the task to be conducted and the organisation responsible for this stage. The minimum number of competent people each organisation need to have can easily be determined. for example, hot commissioning requires a minimum of two EC&I engineers, one to conduct the tests along with the clients' operations to accept the tests have been completed, the second to verify the test results and validation from the system integrator engineer and finally either a second engineer or manager to verify the validation.

SLC Phases	10		
SLC Avctivities	Functional Safety Assessment - Stage 3		
Clauses of BS EN 61511-1	5.2.6.1 of Clause 5		
Activity Purpose/Objectives	To investigate the evidences through the independent cross-check and arrive at a judgement on the functional safety achieved by the SIS after installation and commissioning, it assess that: - safety requirements are met, - safety requirements per se are correct, and - other review/check activities (including verification, FS audit and validation) have been effectively and correctively performed.		
Tasks to be Carried out	Functional Safety Assessment (FSA 3)		
Orgnisations Responsible for activities	Tata		
Persons Responsible for activities	Tata Process Safety Engineer	Insert name here	
Competence	Formal Training	TUV 61508 / 61511 Functional Safety	
	Experience	Minimum 3 years experience in Functional Safety Assesments	
	Demonstration of Knowledge	Minimum 1 FSA3 Document peer reviewed in last 5 years	
Inputs/Documentation		DMS Ref:	Rev No.
	FDS	Insert Document number Here	Insert Revision number Here
	SRS	Insert Document number Here	Insert Revision number Here
	FSA2	Insert Document number Here	Insert Revision number Here
	HS3	Insert Document number Here	Insert Revision number Here
	HS4	Insert Document number Here	Insert Revision number Here
	HS5	Insert Document number Here	Insert Revision number Here
	Hot Commissioining procedure / SAT	Insert Document number Here	Insert Revision number Here
Outputs/Evidence	FSA 3 Report	Insert Document number Here	Insert Revision number Here
Verifier	Tata Process Safety Engineer	Insert name here	
Competence	Formal Training	TUV 61508 / 61511 Functional Safety	
	Experience	Minimum 3 years experience in Functional Safety Assesments	
	Demonstration of Knowledge	Minimum 1 FSA3 Document peer reviewed in last 5 years	
Independence	Must not have been involved in FSA3 assessment		
Acceptence	Tata Project Manager	Insert name here	

Table 31: New FSMP detailed stage checklist

The individual tab sheets can be used to add the names of each person conducting the tests and provide the specific details of all the documentation reviewed as inputs and the completed documentation as outputs or evidence. Whilst there is crossover between the header section of the front page and each tab sheet, this needs to remain as is, this demonstrates the lifecycle element that the completed documentation refers too.

If this procedure is to be used outside of Tata steel, then the word Tata can be switched with the word client i.e., the organisation where the work is taking place, responsibility for completing tasks and producing documentation can be outsourced, but the accountability remains with the organisation.

The created checklist is designed to protect employees by reducing the number of and severity of the process safety incidents that occur globally by ensuring that the right competence level of individuals and the right documentation is in place at each stage of the functional safety lifecycle. The Author through experience has seen that the root cause of many incidents is the failing of a management system, this checklist would address some of the issues seen by not having the right documentation, competent people or a standardised system in place.

7 Interview 2 analysis

A copy of the proposed checklist as seen in appendix 13 was provided to the process safety manager for their review. From this a second interview was scheduled to review and finalise the proposal.

The process safety manager concluded that the FSMP is incredibly detailed and upon successful trial during the next project would be incorporated into the functional safety policy at the next review after this. The document would provide standardisation in the approach to functional safety and demonstrating the competencies of people involved at each stage and the completion of the validation or verification of each stage.

The process safety manager commented on the cold and hot commissioning where the procedure is split from the activity, see table 32, and questioned why this was not combined. The researcher pointed out this was a deliberate action to demonstrate the importance of the procedure to be followed and the need to ensure this procedure is in place, reviewed and signed off before the onset of commissioning. This ensures any errors or omissions in the first draft are included in the final revision to allow the commissioning to be as effective as possible. Changing procedures and getting sign off whilst you are also commissioning is fraught with danger. The process safety manger however still wanted these activities combined see table 33.

5						
Installation, Commissioning and Validation						
Clause 14 & 15						
FAT	**Installation**	**Cold commissioning procedure**	**Cold Commissioning**	**Proof Test**	**Hot commissioning procedure**	**Hot Commissioning / SAT**
System integrator	**EC&I Contractor**	**Tata**	**Tata**	**System integrator**	**Tata**	**Tata**
System integrator Engineer (1)	Tata projects E,C & I Engineer (1)	Tata projects E,C & I Engineer (1)	Tata projects E,C & I Engineer (1)	System integrator Engineer (1)	Tata projects E,C & I Engineer (1)	Tata projects E,C & I Engineer (1)
System integrator Manager (1)	Tata projects E,C & I Engineer (2)	Tata projects E,C & I Engineer (2)	Tata projects E,C & I Engineer (2)	Tata projects E,C & I Engineer (1)	Tata projects E,C & I Engineer (2)	Tata projects E,C & I Engineer (2)
Not involved in creating FAT procedure	Not involved in the installation process	Not involved in creating procedure	Not involved in commsiioning activities	Not involved in creating procedure	Not involved in creating procedure	Not involved in commsiioning activities
Tata Operations (1)	**Tata Project Manager (1)**	**Tata Project Manager (1)**	**Tata Operations (1)**	**Tata Operations (1)**	**Tata Operations (1)**	**Tata Operations (1)**
Tata Project Lead Engineer (1)	N/A	N/A	N/A	N/A	N/A	System integrator Engineer (1)
Tata Project Manager (1)	N/A	N/A	N/A	N/A	N/A	System integrator Manager (1)
Not involved in FAT procedure	N/A	N/A	N/A	N/A	N/A	Not involved in the Hot Commissioning / SAT activities

Table 32: Installation, commissioning, and validation section prior to modification.

5				
Installation, Commissioning and Validation				
Clause 14 & 15				
FAT	**Installation**	**Cold Commissioning including procedure**	**Proof Test**	**Hot commissioning & SAT including procedure**
System integrator	**EC&I Contractor**	**Tata**	**System integrator**	**Tata**
System integrator Engineer (1)	Tata projects E,C & I Engineer (1)	Tata projects E,C & I Engineer (1)	System integrator Engineer (1)	Tata projects E,C & I Engineer (1)
System integrator Manager (1)	Tata projects E,C & I Engineer (2)	Tata projects E,C & I Engineer (2)	Tata projects E,C & I Engineer (1)	Tata projects E,C & I Engineer (2)
Not involved in creating FAT procedure	Not involved in the installation process	Not involved in commsiioning activities	Not involved in creating procedure	Not involved in creating procedure
Tata Operations (1)	**Tata Project Manager (1)**	**Tata Operations (1)**	**Tata Operations (1)**	**Tata Operations (1)**
Tata Project Lead Engineer (1)	N/A	N/A	N/A	N/A
Tata Project Manager (1)	N/A	N/A	N/A	N/A
Not involved in FAT procedure	N/A	N/A	N/A	N/A

Table 33: Installation, commissioning and validation section post modification.

The ultimate point was a suggested update where the new checklist front page could highlight minimal internal and external team numbers required for the overall project as the minimum numbers and organisations responsible would not change. This suggestion was implemented in the final revision of the proposal and is shown in Table 34 and for the individual tabs, the sections that the project manager needs to be complete should be highlighted i.e., they cells could be greyed out to indicate a response required.

Resource Requirements	
Tata	
Tata Process Safety Engineer	2
Tata Project Manager	1
Tata Project Lead Engineer	1
Tata projects E,C & I Engineer	2
Tata Operations	1
Contractor	
System integrator Engineer	1
System integrator Manager	1

Table 34: Proposed resource requirements front page.

The process safety manager however did have some concerns, these were generic concerns and not directly related to the proposed procedure, these included generic concerns over use of checklist; concerns over updating the checklist if the standard changes and the control of checklist – i.e., using paper copies containing older revisions.

This can easily be addressed by version control of the documentation and a competent verifier would cross check documentation and have intimate knowledge of the latest standards.

The overall proposed checklist addresses a gap by creating a standardised way of managing competence, verification and validation throughout the functional safety lifecycle. Controlling these elements will reduce the number of process safety incidents identified in section one and ultimately ensure safety of employees and the general public.

8 Conclusion

The overall aim of the project was to investigate the effectiveness of functional safety planning, verification, validation and competence throughout the entire safety lifecycle by using a case study project from Tata steel, Port Talbot works.

To understand the aim in more detail, several objectives were created to cover five key elements that together answered the project aim.

The evaluation around the effectiveness and complexity of current functional safety planning specifically around competence, validation, verification, and the use of checklists was completed in the literature research. This research identified that the FSM plan should be created at the onset of each project, however this does not align to Tata's functional safety which states the FSMP should be started once the HS3, and associated LOPA identify the need for additional measure to attain tolerable. This approach is a common-sense approach, but the competencies and verifier of the hazard studies and LOPA need to be captured elsewhere. It should be noted that that the HS3 and LOPA are essential documents, where any errors, assumptions, or omissions here will follow through each stage of the project.

The research indicated that checklists can be useful if used correctly. The biggest risks identified in suing checklists are incorrect use to latest revisions e.g., old versions stored on personal drives; updating of checklists e.g., checklists are not matching current standards and implied competence, having a checklist to follow could be misconstrued as competence. However, Tata have been using checklists throughout their operation for many years.

There was a clear alignment of the literature research and Tata analysis of what constitutes what is competency, which being demonstratable skills, knowledge, and behaviour. However, a discrepancy does exist in both literature and Tata analysis of exactly what and how these elements are demonstrable and how ongoing assessment takes place.

Validation and verification is clear in the literature research, but there is a distinct lack of knowledge of these within the Tata environment. This could be attributed to Tata having a sign off procedure for most of their documents. Whilst sign off is acceptable as a term, the independence and competency of this individual needs to be aligned to the regulations not just the immediate manager.

The current knowledge level of functional safety, competency, validation, and verification within Tata steel Port Talbot was answered by means of distributing eighty questionnaires throughout seven area managers to disseminate to their teams. The response rate was seventy five percent with nine not completed correctly leaving fifty-one useful responses. The response rate was high as the researcher worked in the same company had influence over the seven area managers. The nine questionnaires not fed back correctly could be down to many factors but expect lack of knowledge and understanding of the topic or the recent news of a predicted three thousand jobs cuts to be the main influences. It can be seen form question two of the questionnaire that the perceived knowledge of respondents reduced on functional and machinery safety compared to the same responses for ATEX, DSEAR and process safety. Functional safety is a very specific topic which is not encountered on a daily basis which would reflect this reduction in perceived knowledge.

Questions four through to eight backed up the drop in perceived knowledge, it is clear from the more qualitative answers that the understanding of functional safety is not embedded and as such Tata should review the implementation and training previously provided.

The function of the central process safety team through each aspect of the lifecycle is also unclear. Whilst the operations teams are clearly responsible for many elements within the life cycle, question three identified that when it came to the discrete sections of the lifecycle such as verification; validation; independence; SRS and the FSMP the majority of the respondents chose the process safety team as the responsible party.

An interview was also completed with the current process safety manager once the case study project was completed to gain their understanding of the policy and implementation. At first a defensive position was overcome, and an insightful discussion held. It is clear that a policy is in place, but the documentation set is not to the required standard and should be reviewed by a third-party independent body and onsite competent persons. The use of the documentation was still in its infancy and the process safety manager welcomed the feedback of the findings both positive and negative as these initiates change.

The current functional safety planning system used on the plant-based case study project was evaluated to understand how the theory and questionnaire feedback was used in a real-life example. It is clear to see that the competency of the team involved in any project solely relies on the project manager. There should be a gate review once the LOPA is complete and identifies further actions. This gate review should be a review of the HS3 and LOPA to ensure accuracy and initiation of the FSMP.

The lack of competence within the project team led to numerous errors within the project that increased both costs and duration. The lack of upfront competency meant that the contractor selection for implementation did not include any functional safety, it was only noticed toward the later stage that essential functional safety documentation was missing. A local third-party contracting company offered to assist the chosen contractor in producing the required documentation. This led to friction between Tata, the chosen contractor and third party. Had Tata not identified the missing documentation the project could have been completed and signed off without verification that the solution implemented was effective or as per design.

To complete the final element the researcher produced a standard checklist that identifies the organisation and persons responsible competencies required for all individuals throughout the functional safety life cycle. The checklist concentrated on the positives from the completed FSMP in the case study and the areas of improvement identified from the questionnaires, interview, and case study project. The questionnaire produced a one hundred percent success rate when questioned whether a checklist would be helpful. The completed checklist can be applied to any future functional safety management plan irrespective of the companies involved; the industry that it is used in or the current level of competence around functional safety. The single document format containing essential organisational and competency requirements can be used in all process safety applications irrespective if functional safety is a requirement or not. The ability to demonstrate these aspects are essential in all projects.

Whilst the aim of this research project was completed, the study identified numerous areas of future research that can be undertaken, these include the effectiveness of the new proforma on future functional safety projects either within TATA or externally; the role of a central process safety within an organisation and its effect on the process and the demands on a project manager within a functional safety project.

The researcher aimed to reduce any bias by allowing the seven area managers to disseminate the questionnaires through their team and chase responses. Whilst this reduced bias from the researcher, there is an inevitable amount of bias in the people selected by the area managers to complete the questionnaires.

The sample proportion was determined as all the electrically biased personnel throughout tata and included both days and shifts. The sample population deliberately ignored the mechanical biased personnel as functional safety focuses on the electrical, control, instrumentation, and automation aspects within a process safety project. The analysis of the sample population will rarely reflect the actual population, there will always be a slight variation in the mean.

8.1 Next steps

The conclusion has identified several actions that tata needs to complete to close out the learning identified throughout this dissertation. This has been discussed with the process safety manager and sent via email for their consideration, they include:-

1) Utilise the proposed checklist on a live functional safety project.
2) Review the existing functional safety documentation with a third-party expert for alignment to standards.
3) Review the existing functional safety training and plant implementation to improve knowledge and competence.
4) Review the interface between central process safety, manufacturing areas and project teams to ensure alignment.
5) Review the expectation of the project managers within a project environment, especially in relation to determining the core competencies of the required team members.
6) Integrate the new checklist into the functional safety documentation.

8.2 Learning points

Throughout the project there were several learning points for the researcher, which could have assisted in the dissertation data collection and timeline.

The first learning opportunity concerned the importance of the data collection plan, identified through completing a Lean Six Sigma black belt course and the use of Minitab to complete statistical analysis of the collected data. Understanding of the question and the type of responses expected should dictate how and when the data is collected, the sample size and the method of data evaluation i.e., one way hypothesis tests etc.

The second learning point was to expect the unexpected, the timeline allowed for slack and known or anticipated project risks . However it should be noted that as well as the known known and unknowns, there are unknown unknowns, the reasons for these are explained further in section 10, but the upfront work to get ahead of schedule and the slack input at the tail end of the programme ensured these remain as issues and not impacted the completion of the research.

The final learning point was around the use of Microsoft forms or similar applications, which could have made distributing the questionnaire and getting high level analysis on the results a quicker and simpler process.

9 Contribution to literature

This dissertation contributes to knowledge as other process safety and especially functional safety managers throughout the world both within the steel industry and other process industries will be able to undertake a standard approach to creating a functional safety management plan that complies with 2023 UK legislation that can be used before any project commences.

Where countries outside of Europe or the UK utilise this approach, it is essential that this is reviewed against the legislation and directives associated with that country as there may be discrepancies.

Where legislation and directives vary across the world, this does not render the checklist useless. The backbone of the checklist will always be relevant, and the key input and output documentation of each stage is unlikely to vary.

The next section identifies the timeline to completing the research, implementing the project, and completing the analysis. The timeline also identifies risks that the researcher has identified and where possible identified counter measure should these risks materialise.

10 Timeline and project risks

To ensure the research is completed prior to the submission date of April 2024 a high-level project timeline was created, this can be seen in appendix 14. Whilst each element of the timeline is not fixed and can be adjusted to suit the researcher, the timeline does identify key fixed milestones such as the submission date.

The timeline further identifies the risks within the research, with the biggest risk identified is that the relevant data from the selected project or key personnel for interviews will not be available within the desired period. To overcome the known project risks and account for any unknown risks that would materialise the timeline has been established to complete the report in March, this provides additional time to review the completed project whilst providing an element of slack should something unforeseen arise.

The researcher has a back-up plan for all three risks they are being the interview, the questionnaire, and the case study. Firstly for the interview, a second person i.e. the Tata Steel process safety director can be called upon to replace the Tata process safety manager, secondly a backup engineering company can be used to complete the questionnaires should the selected industry engineering experts not be willing to participate and finally a smaller case study project completed within the last eighteen months could be used should the current case study project not be completed on time, but there is a risk that the required level of process safety interaction may not be included and as such are not one hundred percent applicable. Both primary interviewees and substitute interviewees have been approached for consent and initial timeslot agreement.

10.1 Research delays

Throughout the research there were several areas that resulted in delays that the researcher did not foresee at the onset of the report. Although these issues arose whilst the identified projects did not come to fruition the back-up measures in place were resilient enough to cope with the new issues.

The initial timeline created planned the research to be completed in February 2024 which allowed four weeks for fine tuning prior to the early deadline, this slack has been taken up by several issues which was not originally planned to include :-

1) New baby born which consumed a lot of the researcher’s time. To overcome come this a lot of the work was completed late in the evenings and during work time to ensure the dissertation did not slip further.
2) Loss of immediate family member during the summer holiday period. The key events during this time were around the data collection period. The researcher was ahead of plan and as such the questionnaires had already been sent out, the case study review had started but the interview had to be rearranged for the following month. Overall little time was lost during this event.
3) Loss of family pet at the onset of the research which disrupted the first few weeks of the project, prompting the researcher to ensure they were ahead of plan in case other incidents occurred.
4) The researcher changed roles during the research. Whilst this caused disruption it did not affect the dissertation timeline as at this point all the data was collected and the project was eighty percent completed.
5) Job security risks throughout the project. Tata announced decarbonisation plans internally in July 2023 with potential job reductions and reconfirmed in October 2023. This did not influence the timeline but has influenced the feedback of the questionnaires and interviews as sitewide moral has reduced.

11 References

Adams, W C (2015) Conducting Semi structured interviews. Available at: Conducting Semi-Structured Interviews - Handbook of Practical Program Evaluation - Wiley Online Library Accessed 15/12/2023.

Avila, L (2017) Safety lifecycle seminar. Available at: Safety life cycle seminar IEC61511 (slideshare.net) Accessed 24/06/2023.

Bell, R (2017) Introduction and Revision of IEC 61508. Available at: Introduction-IEC-61508-Bell-October-2016.pdf (esc.uk.net) Accessed 14/08/23.

Cabletalk (2023) The importance of competence. Scottish Electromechanical industry magazine, October 2023 pp54-56. Available at: The importance of competence.pdf (cabletalkmagazine.com). Accessed 16/11/2023.

CCOHS (2023) Risk Assessment. Available at: CCOHS: Hazard and Risk - Risk Assessment. Accessed 19/07/2023.

Celik, A Y (2022) Determination of the effectiveness of a template for lesson planning. International journal of education, technology, and scientific research Vol 7(20) 2402-2416. Available at: Determination of the effectiveness of a template for lesson planning (ijetsar.com) Accessed 29/05/2023.

CIMAH (2023) ten worst process safety incidents. Available at: CIMAH & Process Safety Blog | Control of Industrial Major Accident Hazards | Process Safety: Top 10 worst process safety incidents in history. Accessed 29/05/2023.

CPS (2023) Process safety definition. Available at: Process Safety Incident/Event | AIChE. Accessed 30/05/2023.

Davies, R L (2023) DSEAR: A comprehensive guide for compliance. Available at: DSEAR: A Comprehensive Guide for Compliance - Orbis Environmental and Safety Accessed 30/05/2023

Dearden, TH (2016) Scaremongering and IEC61511. Available at: (7) Scaremongering & IEC 61511 | LinkedIn. Accessed 30/05/2023.

Éclair (2023) ECLAIR_IEC61508.pdf (bugseng.com) Accessed 28/05/2023

Exida (2023) Functional Safety Management Planning. Available at: Functional-Safety-Management-Planning.pdf (exida.com). Accessed 23/07/2023.

Fox, N (2006) Using Interviews in a research project. Available at: Using Interviews in a research project.. Accessed 04/01/2023.

GM International (2021) 61511 Safety life cycle. Available at: IEC 61511 Safety Lifecycle mini guide (gminternational.com) Accessed 25/05/2023

Gov.UK (2020) Dangerous Substances and Explosive Atmosphere Regulations. Available at: Dangerous Substances and Explosive Atmospheres Regulations JSP375 Vol1 Chap 9 (publishing.service.gov.uk). Accessed 19/07/2023.

HSE (2023) DSEAR Regulations. Available at: DSEAR Regulations - Fire and explosion (hse.gov.uk) Accessed 28/05/2023.

IEC 61508 (2010). Available at: compass (astm.org) Accessed 22/05/2023.

IEC 61511 (2017). Available at: compass (astm.org) Accessed 22/05/2023.

IEEE (2016) Verification. Available at: Where formal verification can help in functional safety analysis | IEEE Conference Publication | IEEE Xplore Accessed 17/09/2023

Jensen, R J; Szulanski, G (2007) Template use and the effectiveness of knowledge transfer. Management Science 53(11):1716-1730. Available at: Template use and the effectiveness of knowledge transfer. Accessed 23/05/23.

Knight, DC (2005) Functional safety management planning. Available at: Functional-Safety-Management-Planning.pdf (exida.com). Accessed 01/06/2023.

Leavy, P (2014) The oxford handbook of qualitative research. Chapter 15, Unstructured and semi structured interviewing. Pp 424-456. Available at: The Oxford Handbook of Qualitative Research - Patricia Leavy - Google Books Accessed 28/12/2023.

Mathwork (2023) TUV Toolkit. Available at: IEC 61508 Support in MATLAB and Simulink - Automotive Industry Standards - MATLAB & Simulink (mathworks.com) Accessed 29/12/2023.

Method (2023) competency register tool. Available at: What is the Competency Register Tool? (methodcompreg.com) Accessed 16/06/2023.

Method (2023a) Independence. Available at: What is Functional Safety Management? (methodfs.com) Accessed 16/07/2023.

Mukundan, J; Ahour T (2009) A review of textbook evaluation checklists across four decades (1970-2008) Available at Research for Materials Development in Language Learning: Evidence For Best ... - Google Books. Accessed 31/05/2023 p336-349.

NIH (2023) What are competencies. Available at: What are competencies? | Office of Human Resources (nih.gov). Accessed 13/08/2023.

Nulty, D (2008) The adequacy of response rates to online paper surveys. Available at: The adequacy of response rates to online and paper surveys: what can be done? (educationopportunities.co.uk). Accessed 23/08/2023.

OSHA (2023) Hazard Identification. Available at: Safety Management - Hazard Identification and Assessment | Occupational Safety and Health Administration (osha.gov) Accessed 21/07/2023.

OSHA (2023a) Process safety management standards (US) Available at: Process Safety Management - Standards | Occupational Safety and Health Administration (osha.gov) Accessed 30/05/2023.

Ronseal (1994) Does exactly what it says on the tin. Available at: Home and Garden DIY Products | Ronseal Accessed 24/11/2023.

Science Direct (2023) Layer of Protection Analysis. Available at: Layer of Protection Analysis - an overview | ScienceDirect Topics. Accessed 24/07/2023.

Smith, D; Simpson, K (2004) Functional safety A straight forward guide to applying IEC61508 and related standards second edition. ISBN 0 7506 6269 7 Functional Safety - David Smith, Kenneth Simpson - Google Books

Soliman, D; Frey G (2011) Validation definition. Available at: Verification and validation of safety applications based on PLCopen safety function blocks - ScienceDirect Accessed 17/09/2023.

Stuart, L (2019) Safety Instrumented Functions (SIF). Available at: Back to Basics 03 - Safety Instrumented Function (SIF) | exida. Accessed 28/05/2023.

Synergen (2023) Process safety incidents. Available at: 4 Major Accidents in the 21st Century - SynergenOG Accessed 29/05/2023

TUV (2023) Functional safety checklist. Available at: Functional Safety Starter Kit: Documentation tools and Guidelines | TÜV SÜD (tuvsud.com) Accessed 07/09/2023

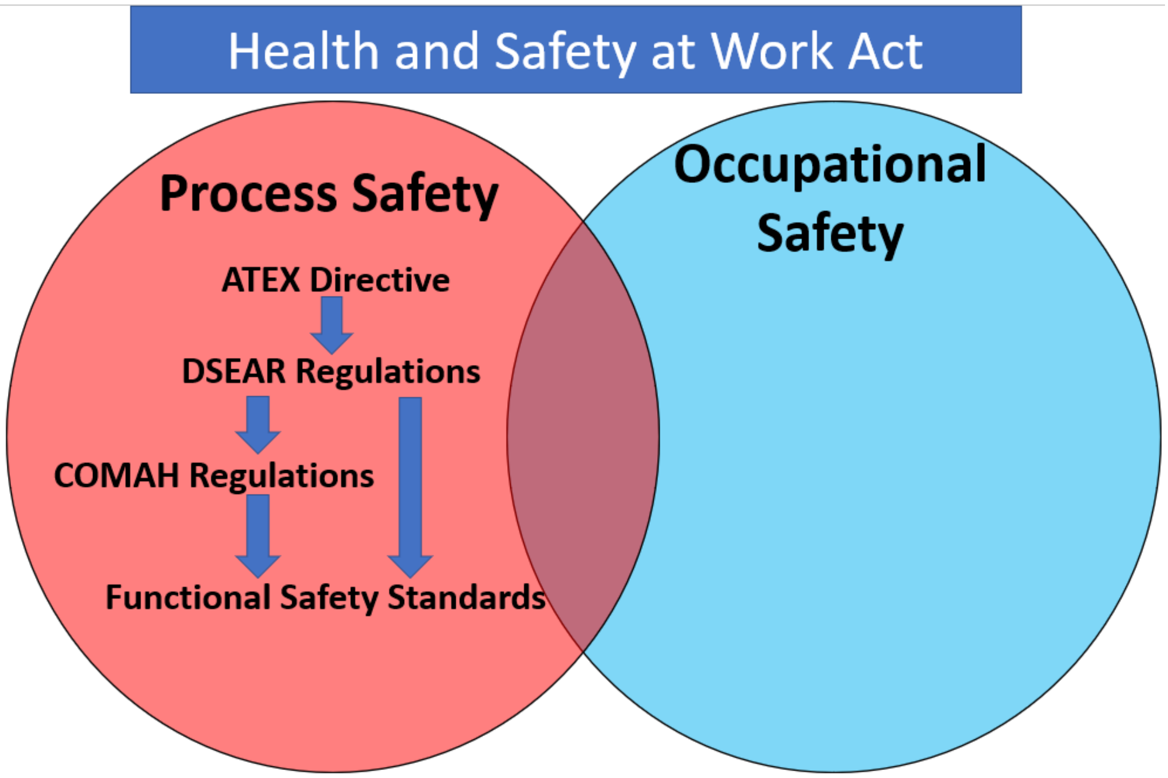
Walliman, N (2005) Your research project: a step by step guide for the first time researcher. Available at: (PDF) Your research project: a step-by-step guide for the first-time researcher_Walliman_2005 | Dr Sunarsih - Academia.edu. Accessed 05/01/2023.

Wetherill, D (2023) Verbal comment, March 2023 functional safety refresher training course.

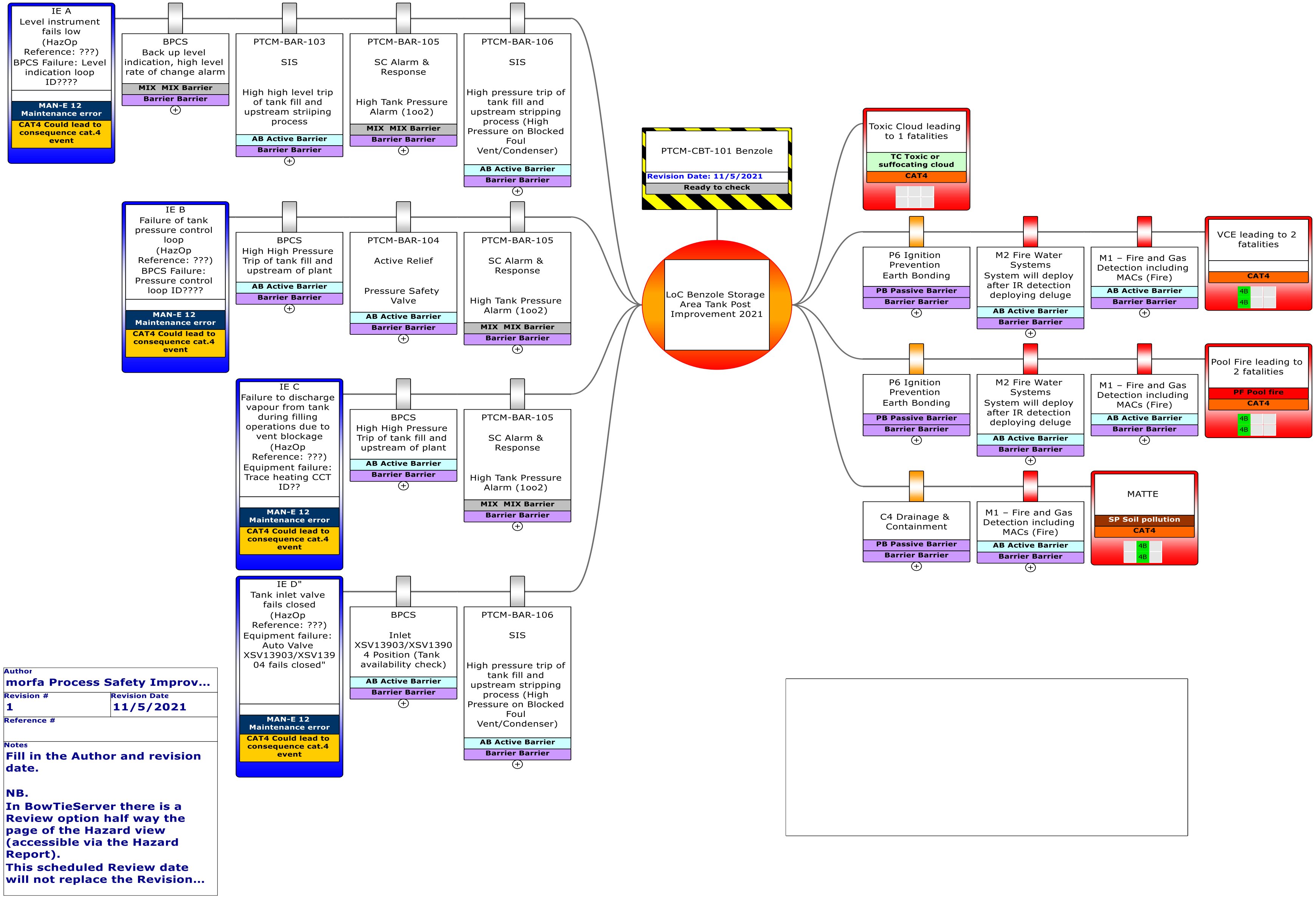
White, R W (1959) Motivation reconsidered: The concept of competence. Psychological Review, 66(5), 297-33. Available at: Motivation reconsidered: The concept of competence. (apa.org) Accessed 29/05/2023.

Wolters, Kluwer (2019) Process safety management Process Safety Management: What You Need to Know | Wolters Kluwer Accessed 29/05/2023.

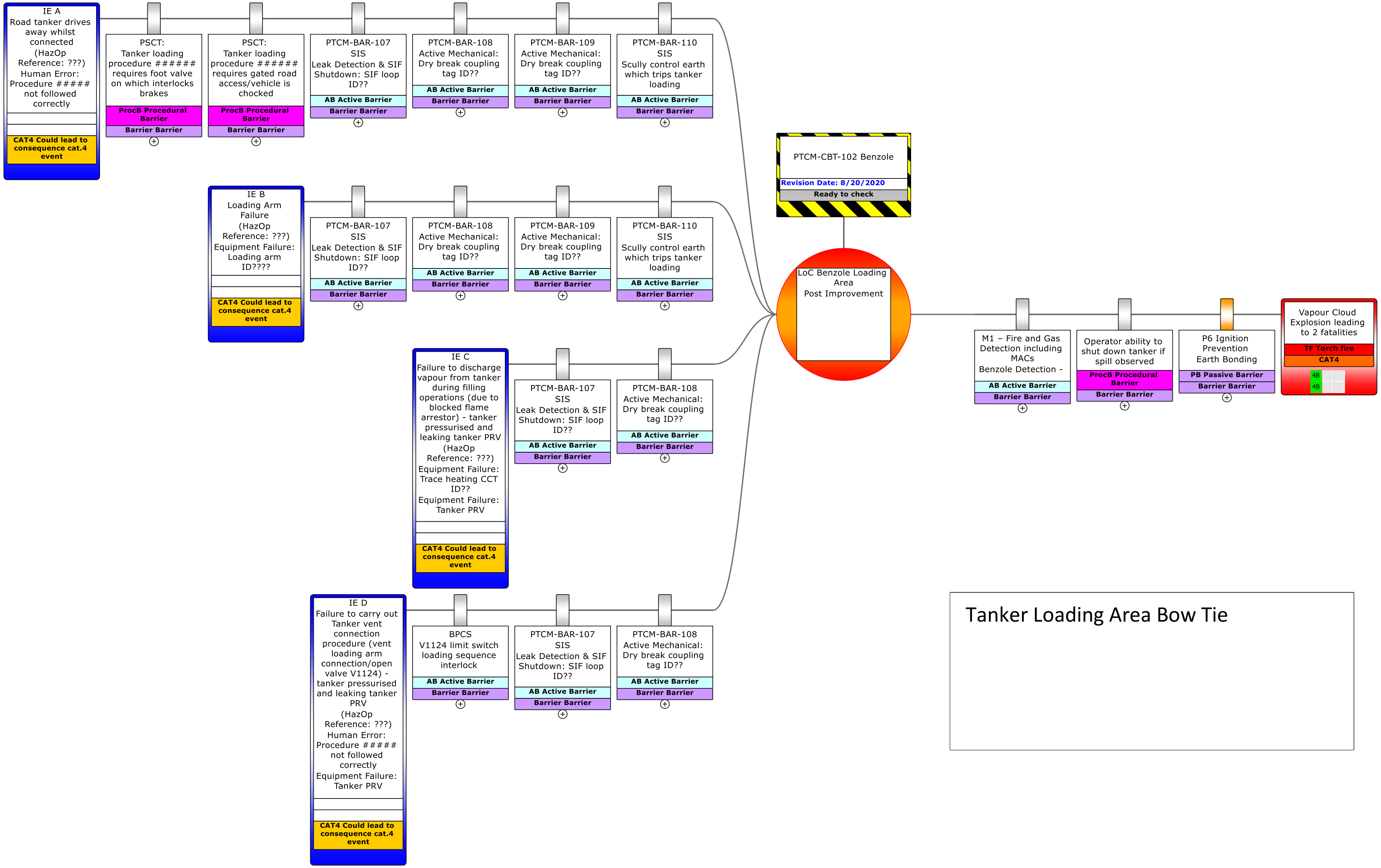
Appendix 1 – Relationship of various process safety standards



Appendix 2 – Benzole project bow tie diagrams



IE A
Level instrument fails low (HazOp Reference: ???) BPCS Failure: Level indication loop ID????
MAN-E 12 Maintenance error
CAT4 Could lead to consequence cat.4 event
BPCS
Back up level indication, high level rate of change alarm
MIX MIX Barrier
Barrier Barrier
PTCM-BAR-103
SIS
High high level trip of tank fill and upstream striiping process
AB Active Barrier
Barrier Barrier
PTCM-BAR-105
SC Alarm & Response
High Tank Pressure Alarm (1oo2)
MIX MIX Barrier
Barrier Barrier
PTCM-BAR-106
SIS
High pressure trip of tank fill and upstream stripping process (High Pressure on Blocked Foul Vent/Condenser)
AB Active Barrier
Barrier Barrier
IE B
Failure of tank pressure control loop (HazOp Reference: ???) BPCS Failure: Pressure control loop ID????
MAN-E 12 Maintenance error
CAT4 Could lead to consequence cat.4 event
BPCS
High High Pressure Trip of tank fill and upstream of plant
AB Active Barrier
Barrier Barrier
PTCM-BAR-104
Active Relief
Pressure Safety Valve
AB Active Barrier
Barrier Barrier
PTCM-BAR-105
SC Alarm & Response
High Tank Pressure Alarm (1oo2)
MIX MIX Barrier
Barrier Barrier
IE C
Failure to discharge vapour from tank during filling operations due to vent blockage (HazOp Reference: ???) Equipment failure: Trace heating CCT ID??
MAN-E 12 Maintenance error
CAT4 Could lead to consequence cat.4 event
BPCS
High High Pressure Trip of tank fill and upstream of plant
AB Active Barrier
Barrier Barrier
PTCM-BAR-105
SC Alarm & Response
High Tank Pressure Alarm (1oo2)
MIX MIX Barrier
Barrier Barrier
IE D"
Tank inlet valve fails closed (HazOp Reference: ???) Equipment failure: Auto Valve XSV13903/XSV13904 fails closed"
MAN-E 12 Maintenance error
CAT4 Could lead to consequence cat.4 event
BPCS
Inlet XSV13903/XSV13904 Position (Tank availability check)
AB Active Barrier
Barrier Barrier
PTCM-BAR-106
SIS
High pressure trip of tank fill and upstream stripping process (High Pressure on Blocked Foul Vent/Condenser)
AB Active Barrier
Barrier Barrier
PTCM-CBT-101 Benzole
Revision Date: 11/5/2021
Ready to check
LoC Benzole Storage Area Tank Post Improvement 2021
Toxic Cloud leading to 1 fatalities
TC Toxic or suffocating cloud
CAT4
P6 Ignition Prevention Earth Bonding
PB Passive Barrier
Barrier Barrier
M2 Fire Water Systems System will deploy after IR detection deploying deluge
AB Active Barrier
Barrier Barrier
M1 – Fire and Gas Detection including MACs (Fire)
AB Active Barrier
Barrier Barrier
VCE leading to 2 fatalities
CAT4
4B
4B
Pool Fire leading to 2 fatalities
PF Pool fire
CAT4
C4 Drainage & Containment
PB Passive Barrier
Barrier Barrier
MATTE
SP Soil pollution
CAT4
Author
morfa Process Safety Improv...
Revision #
1
Revision Date
11/5/2021
Reference #
Notes
Fill in the Author and revision date.
NB.
In BowTieServer there is a Review option half way the page of the Hazard view (accessible via the Hazard Report).
This scheduled Review date will not replace the Revision...



Tanker Loading Area Bow Tie

Appendix 3 – SIS safety life cycle overview

Table 2 — SIS safety life-cycle overview

Safety life-cycle phase or activity		Objectives	Require-ments	Inputs	Outputs
Fig-ure 7 box number	Title		Clause		
1	H&RA	To determine the hazards and hazardous events of the process and associated equip-ment, the sequence of events leading to the hazardous event, the process risks associated with the hazardous event, the requirements for risk reduc-tion and the safety functions required to achieve the neces-sary risk reduction	Clause 8	Process design, layout, manning arrangements, safety targets	A description of the hazards, of the required safety function(s) and of the associated risk reduction
2	Allocation of safety functions to protection layers	Allocation of safety functions to protection layers and for each SIF, the associated SIL	Clause 9	A description of the required SIF and associated safety integrity requirements	Description of allocation of safety requirements
3	SIS safety requirements specification	To specify the requirements for each SIS, in terms of the re-quired SIF and their associated safety integrity, in order to achieve the required functional safety	Clause 10	Description of allocation of safety requirements	SIS safety require-ments; application program safety requirements
4	SIS design and engineering	To design the SIS to meet the requirements for SIF and their associated safety integrity	Clauses 11, 12	SIS safety require-ments Application program safety requirements	Design of the SIS hardware and ap-plication program in conformance with the SIS safety requirements; planning for the SIS integration test
5	SIS installation commissioning and validation	To integrate and test the SIS To validate that the SIS meets in all respects the require-ments for safety in terms of the required SIF and their associ-ated safety integrity	Clauses 14, 15	SIS design SIS integration test plan SIS safety require-ments Plan for the safety validation of the SIS	Fully functioning SIS in conformance with the SIS safety requirements. Results of SIS inte-gration tests Results of the installation, commissioning and validation activities
6	SIS operation and mainte-nance	To ensure that the functional safety of the SIS is maintained during operation and mainte-nance	Clause 16	SIS safety require-ments SIS design Plan for SIS opera-tion and mainte-nance	Results of the op-eration and main-tenance activities

Safety life-cycle phase or activity		Objectives	Requirements	Inputs	Outputs
Figure 7 box number	Title		Clause		
7	SIS modification	To make corrections, enhancements or adaptations to the SIS, ensuring that the required SIL is achieved and maintained	Clause 17	Revised SIS safety requirements	Results of SIS modification
8	Decommissioning	To ensure proper review, sector organization, and ensure SIF remains appropriate	Clause 18	As built safety requirements and process information	SIF placed out of service
9	SIS verification	To test and evaluate the outputs of a given phase to ensure correctness and consistency with respect to the products and standards provided as input to that phase	Clause 7, 12.5	Plan for the verification of the SIS for each phase	Results of the verification of the SIS for each phase
10	SIS FSA	To investigate and arrive at a judgement on the functional safety achieved by the SIS	Clause 5	Planning for SIS FSA SIS safety requirement	Results of SIS FSA
11	Safety lifecycle structure and planning	To establish how the lifecycle steps are accomplished	6.2	Not applicable	Safety plan

Appendix 4 – Questionnaire

<u>Functional Safety Questionnaire</u>

Department ____________________________

Job Title ____________________________

Please circle answer below

Length of service (Yrs.)	0 – 5	6 – 10	11 – 20	21+
Age (yrs.)	18 – 29	30 – 39	40 – 49	50+

Q1) For each of the subjects below, please circle the score based on your current level of knowledge on the subject.

	No Knowledge	Minimal Knowledge	Basic Knowledge	Advanced knowledge	Expert Knowldege
DSEAR	1	2	3	4	5
Process Safety	1	2	3	4	5
Atex	1	2	3	4	5
Functional Safety	1	2	3	4	5
Machinery Safety	1	2	3	4	5

Q2) Are you are aware of the functional safety life cycle. Please circle your answer

Yes / No

Q3) For each aspect of the functional safety life cycle below, please indicate by placing an X in the box for who you believe is responsible for each task. You may indicate more than one area of responsibility.

	Project team	Process safety team	Operation team	Contractor	Not Applicable	Don’t Know
Hazard Identification						
Risk Assessment						
Functional Safety Management Planning						
Layer of Protection Aanlysis						
Audits						
Verification						
Installation						
Operation						
Validation						
Independence						
Commissioning						
Safety requirement specification						
Modification						
Decommissiniong						

Q4) For each aspect of the functional safety life cycle below, please indicate the order of importance from 1 to 10, with 1 being the most important.

Task	Importance
Hazard Identification	
Risk Assessment	
Functional Safety Planning	
Layer of Protection Analysis	
Audits	
Verification	
Installation	
Operation	
Validation	
Independence	
Commissioning	
Safety Requirement Specification	
Modification	
Decommissioning	

Q5) Please provide reasons for the top three identified in Question 4

Position	Reason
1	
2	
3	

Q6) In your own words please describe Functional Safety planning and what it means to you.

Q7) Identify the key components that make up competency.

Q8) In your own words please describe Independence in relation to functional safety.

Q9) Functional safety identifies the importance of verification. Based on your experience please identify the relevance each of the traits for persons conducting verification.

	Not important	Slightly important	Fairly important	Important	Very Important
Competence	1	2	3	4	5
Age	1	2	3	4	5
Personality	1	2	3	4	5
Experience	1	2	3	4	5
Position	1	2	3	4	5
Gender	1	2	3	4	5
Training	1	2	3	4	5
Qualifications	1	2	3	4	5
Attitude	1	2	3	4	5

Q10) Would a checklist indicating key requirements at each stage of the functional safety life cycle be of use in your role. Please circle your answer

Yes / No

Appendix 5 – Interview 1, process safety manager question set.

1) What do you believe is the current competence level around functional safety within Port Talbot Works ?
2) What is your view of using checklists in a functional safety environment ?
3) What is your current view on the Tata Functional safety policy, is it fully comprehensive, how often is it reviewed ?
4) How is Functional Safety competence demonstrated ?
5) What is your view on the Functional Safety Management Plan, Who should complete it and when, how important is it in the safety lifecycle, how well is it used in practice ?
6) What is the involvement of the central process safety team in functional safety projects across site ?

Appendix 6 – Case study project manager question set.

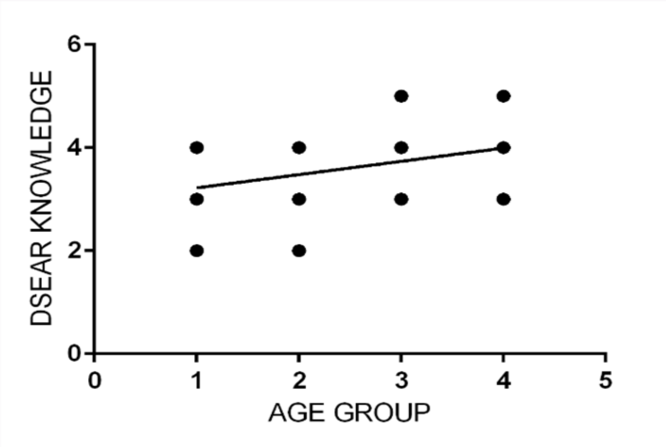
1) What functional safety documentation was used in the project ?
2) What is the functional safety competence of the team and the contractors used ?
3) From a functional safety view, What went well in the project ?
4) From a functional safety view, What did not go well in the project ?
5) How did functional safety implementation effect the project ?
6) How effective was the Functional Safety Management Plan in practice ?
7) What is the involvement of the central process safety team within the project ?

Appendix 7 – Interview 2, process safety manager checklist review

1) What are the benefits of the proposed checklist ?
2) What are the concerns with the proposed checklist ?
3) Could this checklist be included in the existing functional safety policy ?
4) How would the checklist be rolled out ?

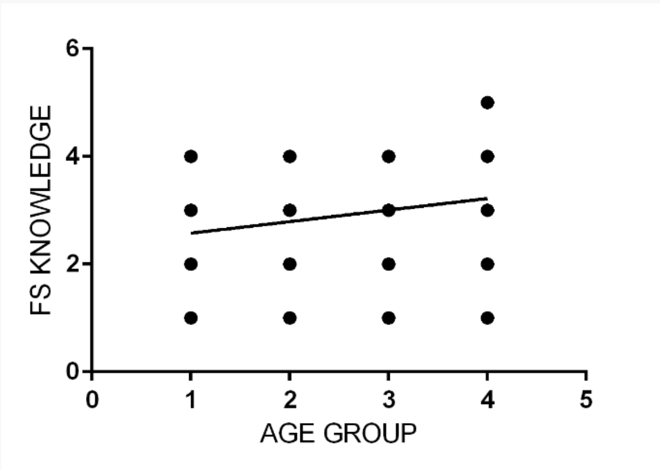
Appendix 8 – Perceived knowledge liner regression

Linear Regression



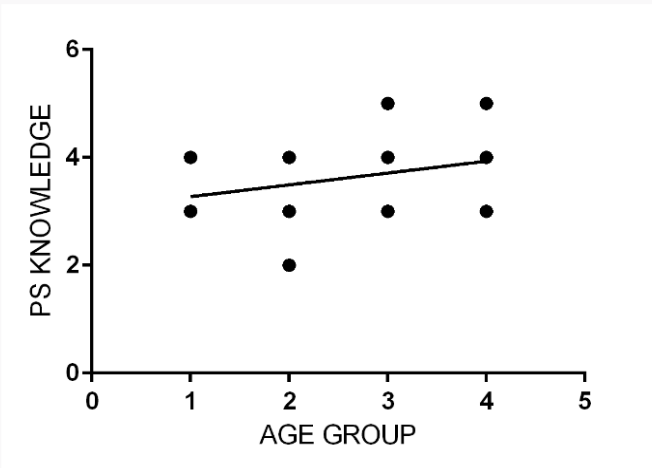
Best-fit values	
Slope	0.2574 ± 0.08357
Y-intercept	2.964 ± 0.2561
X-intercept	-11.51
1/Slope	3.884
95% Confidence Intervals	
Slope	0.08934 to 0.4256
Y-intercept	2.449 to 3.479
X-intercept	-38.62 to -5.801
Goodness of Fit	
R square	0.1622
Sy.x	0.6214
Is slope significantly non-zero?	
F	9.490
DFn,DFd	1,49
P Value	0.0034
Deviation from horizontal?	Significant
Data	
Number of XY pairs	51
Equation	Y = 0.2574*X + 2.964

Linear Regression



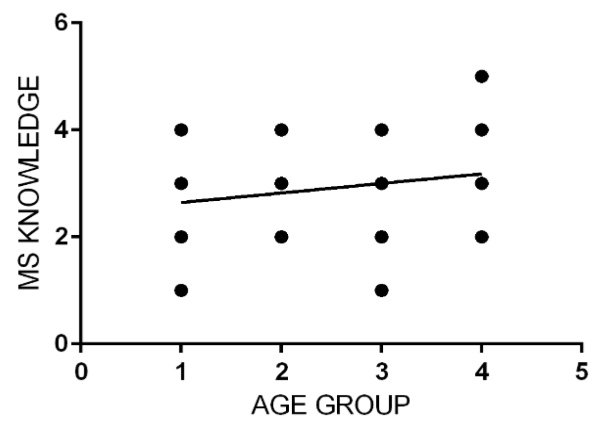
Best-fit values	
Slope	0.2149 ± 0.1391
Y-intercept	2.361 ± 0.4263
X-intercept	-10.99
1/Slope	4.653
95% Confidence Intervals	
Slope	-0.06492 to 0.4947
Y-intercept	1.503 to 3.219
X-intercept	-infinity to -3.091
Goodness of Fit	
R square	0.04644
Sy.x	1.034
Is slope significantly non-zero?	
F	2.387
DFn,DFd	1,49
P Value	0.1288
Deviation from horizontal?	Not Significant
Data	
Number of XY pairs	51
Equation	Y = 0.2149*X + 2.361

Linear Regression



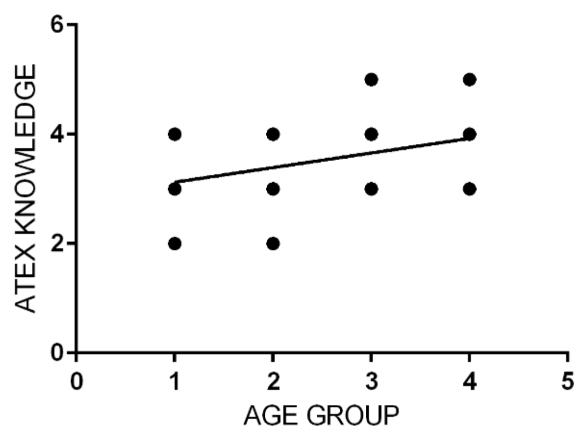
Best-fit values	
Slope	0.2191 ± 0.08224
Y-intercept	3.055 ± 0.2520
X-intercept	-13.94
1/Slope	4.563
95% Confidence Intervals	
Slope	0.05372 to 0.3846
Y-intercept	2.548 to 3.562
X-intercept	-65.76 to -6.679
Goodness of Fit	
R square	0.1266
Sy.x	0.6115
Is slope significantly non-zero?	
F	7.101
DFn,DFd	1,49
P Value	0.0104
Deviation from horizontal?	Significant
Data	
Number of XY pairs	51
Equation	Y = 0.2191*X + 3.055

Linear Regression



Best-fit values	
Slope	0,1787 ± 0,1140
Y-intercept	2,465 ± 0,3494
X-intercept	-13,79
1/Slope	5,595
95% Confidence Intervals	
Slope	-0,05060 to 0,4080
Y-intercept	1,762 to 3,168
X-intercept	-infinity to -4,380
Goodness of Fit	
R square	0,04776
Sy.x	0,8477
Is slope significantly non-zero?	
F	2,458
DFn,DFd	1,49
P Value	0,1234
Deviation from horizontal?	Not Significant
Data	
Number of XY pairs	51
Equation	Y = 0,1787*X + 2,465

Linear Regression



Best-fit values	
Slope	0,2670 ± 0,08587
Y-intercept	2,858 ± 0,2632
X-intercept	-10,70
1/Slope	3,745
95% Confidence Intervals	
Slope	0,09429 to 0,4398
Y-intercept	2,328 to 3,387
X-intercept	-35,62 to -5,341
Goodness of Fit	
R square	0,1648
Sy.x	0,6385
Is slope significantly non-zero?	
F	9,669
DFn,DFd	1,49
P Value	0,0031
Deviation from horizontal?	Significant
Data	
Number of XY pairs	51
Equation	Y = 0,2670*X + 2,858

CONTENTS

1.	INTRODUCTION	5
1.1.	PURPOSE	5
1.2.	OVERVIEW	5
1.3.	SCOPE	5
1.4.	GLOSSARY	6
2.	FUNCTIONAL SAFETY CYCLE	7
2.1.	BS EN 61511 SAFETY LIFE CYCLE (SLC)	7
2.2.	ACTIVITIES OF SAFETY LIFE CYCLE	8
3.	ROLES, RESPONSIBILITIES AND COMPETENCIES	9
3.1.	ROLES AND RESPONSIBILITIES	9
3.2.	COMPETENCIES	9
4.	DOCUMENTATION	10
4.1.	STRUCTURED DOCUMENTATION	10
5.	VERIFICATION, VALIDATION AND FSA PLAN	12
5.1.	VERIFICATION, VALIDATION AND FSA ACTIVITIES	12
5.2.	VERIFICATION PLAN	13
5.3.	VALIDATION PLAN (CARRIED OUT BY OTHERS)	13
5.4.	FSA PLAN	14
6.	MODIFICATION	16
6.1.	PROCEDURE	16
7.	REGULATIONS AND STANDARDS	17

1. INTRODUCTION

1.1. PURPOSE

1.1.1. The purpose of this Functional Safety Plan (FSP) is to specify management and technical activities that are necessary for the achievement of the required functional safety of the Safety Instrumented System (SIS).

1.1.2. The plan includes the control of activities specified in:

- Clauses 6 of BS EN 61511-1, Functional safety - Safety Instrumented Systems for the Process Industry Sector

1.2. OVERVIEW

1.2.1. The SIS shall be designed, built and implemented in accordance with BS EN 61511 for process safety functions.

1.2.2. The life cycle activities associated with the specification, design and integration, information for use, validation and modification are identified in Sections 2 of this document.

1.2.3. The requirements for the SIS are defined in 70057533-56-SRS-0001 Issue 01 Safety Requirements Specification (SRS) (to be provided).

1.2.4. The SIS logic solver (processor, I/O cards, marshalling terminals, and associated panel hardware etc) shall be supplied by Rockwell (the **SIS Supplier**). The life cycle for the safety system detailed design and delivery is further defined in the SIS Supplier's FSP.

1.2.5. The SIS Supplier shall be responsible for the supply of a fully engineered, documented, factory tested, and site tested SIS in accordance with this FSP.

1.2.6. The SIS Supplier shall supply all the SIS logic solver hardware necessary including panels / cabinets, I/O cards, software and licences to meet the SRS. The scope of supply excludes the field sensors, final elements and associated field cabling. All equipment and documentation supplied by the SIS Supplier shall become the property of Tata (the **Client**) following formal acceptance of the system.

1.3. SCOPE

1.3.1. WSP is one party in the functional safety supply chain, the scope of work for functional safety in this project is defined in the contract with the Client. Normally WSP scope based on the Safety Life Cycle (SLC) includes the following:

- Hazard and Risk Assessment (HAZOP)
- Allocation of Safety Functions to Protection Layers and Phase (SILAR)
- Safety Requirements Specification (SRS)
- Functional Safety Assessment (FSA 1, FSA 2 and FSA 3)

1.3.2. The scope of this functional safety plan document is the SIS for the Benzole Storage & Tanker Loading Upgrade project for Tata. The scope of the safety system covers process safety functions.

1.4. GLOSSARY

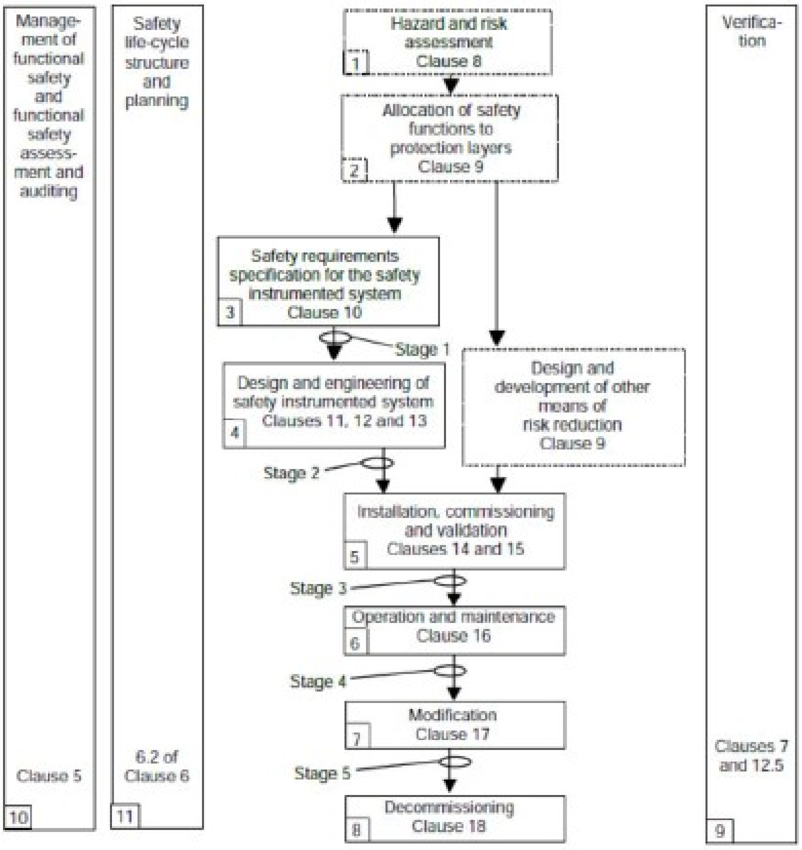
Glossary	Definition
FAT	Factory Acceptance Test
FSM	Functional Safety Management
FSA	Functional Safety Assessment
FSP	Functional Safety Plan
HAZOP	Hazard and Operability
LOPA	Layers of Protection Analysis
BPCS	Basic Process Control System
SIS	Safety Instrumented System
SAT	Site Acceptance Test
SRCF	Safety Related Control Function
SIF	Safety Instrumented Function
SIL	Safety Integrity Level
SRECS	Safety Related Electrical Control System
SRS	Safety Requirements Specification

2. FUNCTIONAL SAFETY CYCLE

2.1. BS EN 61511 SAFETY LIFE CYCLE (SLC)

2.1.1. The following diagram shows the functional Safety Life Cycle specified in Clause 6 of BS EN 61511.

2.1.2. Safety life cycle phase numbers are at the right bottom corner of each phase boxes below. Functional Safety Assessment (FSA) Stage 1 to 5 are also shown on the diagram.



Key:

Typical direction of information flow.

No detailed requirements given in this standard.

Requirements given in this standard.

NOTE 1: Stages 1 through 5 inclusive are defined in 5.2.6.1.4.

NOTE 2: All references are to Part 1 unless otherwise noted.

2.2. ACTIVITIES OF SAFETY LIFE CYCLE

2.2.1. Refer to 70057533-56-FSP-0002 Issue 01 FSP Schedule for the details of all SLC activities shown below and arrangement for this project.

- Hazard and Risk Assessment
- Allocation of Safety Functions to Protection Layers and Phase
- Suppliers Assessment
- Safety Requirements Specification
- Functional Safety Assessment (Stage 1)
- Design and Engineering
- Functional Safety Assessment (Stage 2)
- Installation, Commissioning and Validation
- Functional Safety Assessment (Stage 3)

3. ROLES, RESPONSIBILITIES AND COMPETENCIES

3.1. ROLES AND RESPONSIBILITIES

3.1.1. According to standards BS EN 61508 and BS EN 61511, persons, departments, organisations or other units which are responsible for carrying out and reviewing each of the SIS SLC phases shall be identified and be informed of the responsibilities assigned to them.

Refer to 70057533-56-FSP-0002 Issue 01 FSP Schedule for the details of the roles and responsibilities allocated for each of activity of SLC for this project.

3.2. COMPETENCIES

3.2.1. According to standards BS EN 61508 and BS EN 61511, the competence management shall be the part of Functional Safety Management (FSM) to ensure that the persons, departments or organisations involved with or responsible for functional SLC activities are competent to complete their assigned duties.

Refer to 70057533-56-FSP-0002 Issue 01 FSP Schedule for the details of the competencies of the individuals carrying out the functional SLC activities for this project.

4. DOCUMENTATION

4.1. STRUCTURED DOCUMENTATION

4.1.1. The functional safety life cycle documentation will comprise at least the following. Refer to 70057533-56-FSP-0002 Issue 01 FSP Schedule for all specific documents of functional safety and document responsibilities for this project.

Safety Life Cycle Phase	Document Category	Project Documentation
Phase 9, 10 & 11	Functional Safety Management and Plan Documentation	• This Functional Safety Plan (Verification/Validation/FSA plan are integrated). • SIS Supplier FSP. • FSA Report.
Phase 1 & 2	Risk Management and Evaluation Documentation	• HAZOP Study Report. • SIL Assessment Report. • Trip & Interlock Schedule.
Phase 3	Requirements Specifications	• SIL-rated Instrument Datasheets. • Safety Requirement Specifications.
Phase 4	Design and Engineering of SIS	• Safety Functional Design Specification. • Safety Hardware Design Specification. • Safety Software Design Specification.
Phase 4, 5 & 9	Test/Inspection/Verification/ Validation Documentation	• Verification Method Document. • Verification Calculations – including supporting information for all components. • Verification records. • Architecture Diagrams for SIFs. • Safety FAT Plan/Report. • Safety SAT Plan/Report. • Proof Test Procedures

4.1.2. The documentation will describe the installation, system or equipment and the use of it. The documentation will be written such that the information is accurate, easy to understand and suits the purpose for which it is intended.

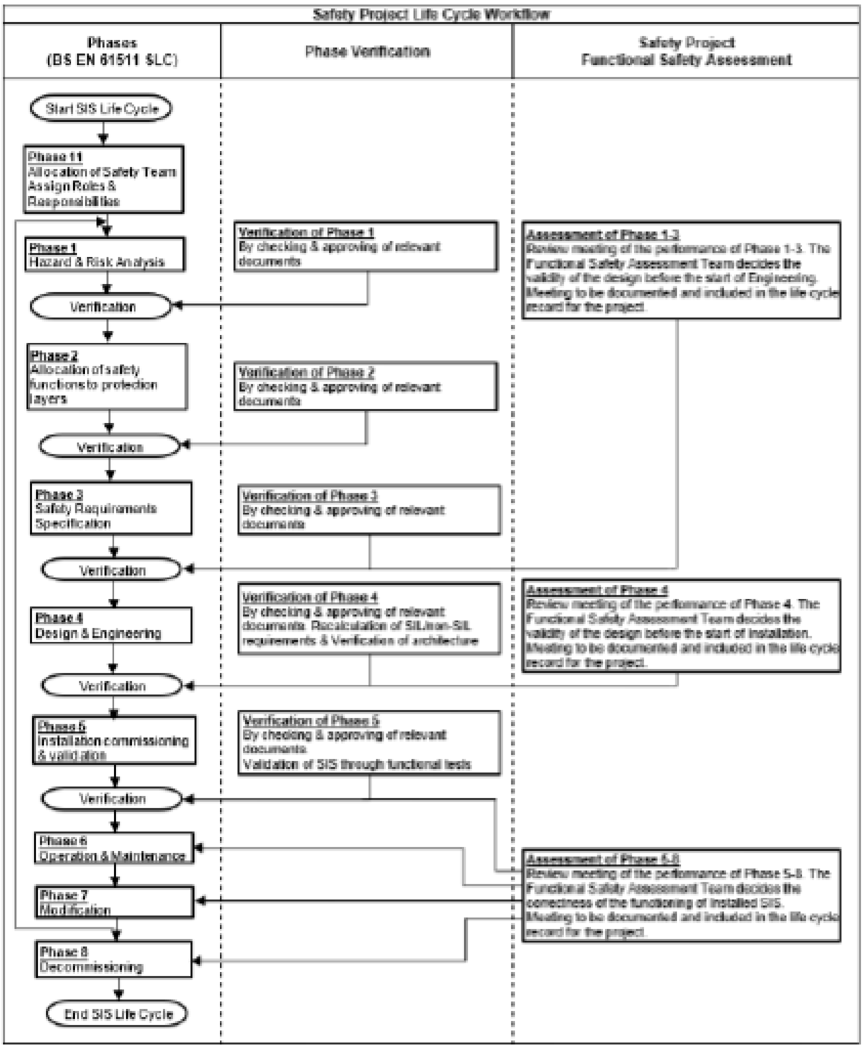
4.1.3. All documentation will be uniquely identified, have designations indicating the type of information, and will be traceable to the requirements of the standards. Documents will have version numbers and a revision index to identify different versions of information, such that the latest or most up to date information is available and retrievable.

4.1.4. All relevant documentation will be revised, amended, reviewed, approved, and be under the control of an appropriate information control scheme.

5. VERIFICATION, VALIDATION AND FSA PLAN

5.1. VERIFICATION, VALIDATION AND FSA ACTIVITIES

5.1.1. The diagram below summarises the verification, validation and FSA activities to be carried out based on BS EN 61511 Safety Life Cycle.



5.2. VERIFICATION PLAN

5.2.1. All relevant documentation will be revised, amended, reviewed, approved, and be under the control of an appropriate information control scheme. Refer to 70057533-56-FSP-0002 Issue 01 FSP Schedule for the details of the verification plan associated with the verifiers, documents under review and corresponding phases of SLC.

5.3. VALIDATION PLAN (CARRIED OUT BY OTHERS)

5.3.1. Validation will comprise of the execution of the following activities

Safety Life Cycle Phase	Activities	Responsibility
Phase 5	Site Acceptance Testing	SIS Supplier
	Installation Verification	C&I Installation Contractor
	Pre-commissioning and Loop Testing (including Instrument Pre-calibration)	C&I Installation Contractor
	Commissioning and Wet Testing (including the Initial Proof Testing)	SIS Supplier or Client

5.3.2. Site Acceptance Testing (SAT)

The SAT is defined as Dry testing (I/O testing) prior to the introduction of fluids and would not be proof testing. This would involve testing of SIFs by manipulation of the process or field devices.

The requirements for testing shall be specified by the SIS Supplier, and should include verification of the following:

- The SIS documentation is consistent with the installed system (as built)
- All SIS equipment is labelled correctly, identified as part of the safety system
- SIS equipment and field wiring is segregated
- All instruments are calibrated
- The safety system properly communicates with the BPCS
- I/O testing (note: this is not a proof testing of the safety system). This will dry test the SIFs.
- The safety system provides proper annunciation and operation display

- The SIS performs as required on loss of utilities (power / air)
- Diagnostic alarm functions perform as required
- Safety system performs under normal and abnormal operating modes as identified in the SRS
- Adverse interaction of the BPCS or any other systems does not affect the safety system.
- The SIS reset functions perform as defined in the SRS
- Proximity to EMC sources
- Security of the safety system
- Proof test intervals are documented

5.3.3. Installation Verification

The installation of all components of the SIS i.e. Sensors, Junction Boxes, Cabling, Logic Solver and Final Elements will be inspected and verified as complying with the detailed design documentation at the end of installation. The installation verification shall be performed and documented by the C&I Installation Contractor and shall be in accordance with Section 19 Testing and Verification of BS 6739.

5.3.4. Pre-commissioning and Loop Testing

On completion of the installation verification, the SIS shall be pre-commissioned and loop tested in accordance with Section 19.8 of BS 6739. Pre-commissioning and loop testing shall be performed and documented by the C&I Installation Contractor.

5.3.5. Commissioning and Wet Testing

On completion of the pre-commissioning and loop testing, the SIS system shall be handed over to the Client for commissioning in accordance with Section 20 of BS 6739. The SIS Supplier shall provide a commissioning and wet testing procedure to test the functionality of each SIF against the SRS.

5.4. FSA PLAN

5.4.1. IEC 61511-1 require that FSA must be planned in advance. The initial planning is part of the project's FSP. As a minimum the FSP specifies the responsibility for FSA, the FSA outputs and the timing of the FSA activities.

5.4.2. A formal FSA plan or procedure should be prepared when the FSA work starts and be structured to address the requirements for planning specified in IEC 61511. IEC 61511-1 sub-clause 5.2.6.1.3 requires that planning for FSA shall consider:

- The scope of the FSA;
- Who is to participate in the FSA;
- The skills, responsibilities and authorities of the FSA team;
- The information that will be generated as a result of any FSA activity;
- The identity of any other safety bodies involved in the FSA;
- The resources required to complete the FSA activity;
- The level of independence of the FSA team.

Refer to 70057533-56-FSP-0002 Issue 01 FSP Schedule for the FSA plan for this project.

6. MODIFICATION

6.1. PROCEDURE

6.1.1. During the initial specification, design and development of the SIS, WSP and the SIS Supplier's quality procedures will be followed to ensure that changes are properly controlled up to system handover to the Client.

6.1.2. Following system handover, the Client shall ensure that there are procedures in place to ensure authorisation and control of changes thought out the operational lifetime of the SIS. The procedures will include a clear method of identifying and requesting work to be done and the hazards that may be affected.

6.1.3. The impact on functional safety as a result of any modification will be analysed. If there is an impact shown, a return will be made to the first phase of the SLC affected by the modification.

6.1.4. Appropriate information will be maintained for all safety system changes, including:

- A detailed description of the modification or change
- The reason for the change
- Identified hazards which may be affected
- An analysis of the impact of the modification on the SIS
- All approvals required for the changes
- Tests to verify that the change was properly implemented and that the SIS performs as required
- Appropriate configuration history
- Tests used to verify that the change has not adversely impacted the SIS

7. REGULATIONS AND STANDARDS

This project shall be implemented to meet requirements for compliance to one or more of the following regulations and standards:

7.1. REGULATIONS

•	COMAH - Control of Major Accident Hazards Regulations
•	MHSWR - Management of Health and Safety at Work Regulations

7.2. STANDARDS

Standard	Description
BS EN 61508	Functional safety of electrical/electronic/programmable electronic safety-related systems
BS EN 61511	Functional safety – Safety instrumented systems for the process industry sector

Appendix 10 – Document 70057533-56-FSP-002 – FSMP schedule

Functional safety management plan – detailed competence

Persons, Departments and Orgnisations involved in the activities of SIS SLC	Orgnisations involved in the activities of SIS SLC	Project Roles	Assessed Competency Level	Notes
JH	Tata	Process Safety Engineer	Practitioner	
HR	Tata	Process Engineering Manager	Practitioner	
CS	Tata	Lead Project EEngineer	Practitioner	
SS	Tata	Project EC & I Engineer	Practitioner	
TR	System Integrator	Automation Engineering	Practitioner	
JS	System Integrator	Automation Engineer	Practitioner	
LJ	Tata	Process Engineer	Practitioner	
SM	Tata	Plant Electrical Engineer	Practitioner	
MB	Tata	Plant Electrical Engineer	Practitioner	
JB	Installation Contractor	Installation Contractor	N/A	

Functional safety management plan – detailed schedule

SLC Phase	SLC Avctivities	Clauses of BS EN 61511-1	Activity Purpose/Objectives	Tasks to be Carried out	Responsibilty	Persons Responsible for activities	Inputs/Documentation	Outputs/Evidence	Status	Verifier
Management and Planning Period										
11	Safety Life Cycle Structure and Planning	6.2 of Clause 6	To produce a functional safety plan covering the scope of the project if a functional safety plan is not provided by others (e.g. the Client) depend on the	**Produce FSP**	WSP	TL	Mandatory Control - Functional Safety Management	70057533-56-FSP-0001 Functional Safety Plan	To be verified	RB
							Guidance Note - Functional Safety Management	70057533-56-FSP-0002 FSP Schedule	To be verified	
Analysis Period										
1	Hazard and Risk Assessment (Note 1) (Note 2)	Clause 8	To determine the hazards and hazardous events of the process and associated equipment, the sequence of events leading to the hazardous event, the process risks associated with the hazardous event, the requirements for risk reduction and the safety functions required to achieve the necessary risk reduction. Typically, HAZOP is employed in this phase.	**HAZOP**	Tata	Project team	HAZOP template			
					Tata	Project team	1826-0052-19-01-001 - Basis of Safety			
					Tata	Project team	1826-0052-19-01-003 - HS2			
					Tata	Project team	1826-0052-19-01-002 - Basis of Design			
					Tata	Project team	1826-0052-19-01-004 - Control Philosophy (URS)			
					Tata	Project team	1826-0052-19-01-009 - BPCS Interlocks			
					Tata	Project team	1826-0052-19-01-010 - SIS Interlocks			
					Tata	Project team	10147-18-01-L-001 - Benzole Plant C_E Schedule			
					Tata	Project team	10147-18-01-L-002 - Benzole Plant Alarm List			
					Tata	Project team	10147-18-01-R-009 - Benzole Plant Functional Safety Description			
					Tata	Project team	Benzole Plant DSEAR Hazardous Area Classification Zoning Plan			
					Tata	Project team	Benzole Plant DSEAR Hazardous Area Classification Zoning Elevation			
					Tata	Project team	TSE204 MCO Benzole Plant Final HAC Report			
					Tata	Project team	IMC006 HAZOP Studies			
					Tata	Project team	70057533-53-2103 - Benzole Storage Tanks P&ID			
					Tata	Project team	70057533-53-2104 - Benzole and Efflu Pump P&ID			
					Tata	Project team	70057533-53-2105 - Tanker Loading P&ID			
					WSP	Project team	70057533-53-REP-0001 tank venting	70057533-30-HAZ-DOC-0001 Tata Benzole Storage HAZOP Report	Verifed with open actions	JOD
								HAZOP Action Sheets	Verifed with open actions	
2	Allocation of Safety Functions to Protection Layers	Clause 9	Allocation of safety functions to protection layers and for each SIF, the associated SIL. Typically, LOPA is employed in this phase.	**1. Level Of Protection Analysis (LOPA)** **2. Trip and Interlock Schedule**	Tata	Project team	Benzole Storage Bowtie			JH
					Tata	Project team	Tanker Loading Bowtie			JH
					Tata	Project team	LOPA Template_Issue 1			
					Tata	Project team	PSG-03.02.56 - LOPA Guide			
					WSP	RC	70057533-53-2103 - Benzole Storage Tanks P&ID	LOPA Worksheet	To be verified	NA
					WSP	RC	70057533-53-2104 - Benzole and Efflu Pump P&ID	LOPA Report	To be verified	NA
					WSP	RC	70057533-53-2105 - Tanker Loading P&ID	Trip & Interlock Schedule	To be verified	NA
					WSP	RC	70057533-30-HAZ-DOC-0001 Tata Benzole Storage HAZOP Report	Updated P&ID	To be verified	NA
					WSP	RC	HAZOP Action Sheets			HR
					WSP	NA				
					WSP	J				
					WSP	JOD				
11	Suppliers Assessment	5.2.5.2 of Clause 5	Issue Supplier Competency Questionnaire to assess the functional safety competency and Functional Safety Management system of all potential suppliers to be involved in the project.	**Issue Supplier Competency Questionnaire to SIS Supplier for Tender**	WSP	TL	Supplier Competency Questionnaire			
					Rockwell	TBC		Response to Supplier Competency	To be verified	TL
								Questionnaire	To be verified	TL
3	Safety Requirement Specifications	Clause 10	To specify the requirements for each SIS, in terms of the required SIF and their associated safety integrity, in order to achieve the required functional safety.	**Safety Requirement Specifications (SRS)**	WSP	TL	LOPA Worksheet	SRS	To be verified	RB
							LOPA Report	SIL-rated Instrument Datasheets	To be verified	RB
							Trip & Interlock Schedule			
							Updated P&IDs			
10	Functional Safety Assessment - Stage 1	5.2.6.1 of Clause 5	To investigate the evidences through the independent cross-check and arrive at a judgement on the functional safety achieved by the SIS to be built, it assess that: - no safety requirements are missed out, - all safety requirements per se are correct, and - other review/check activities (including verification, FS audit) have been effectively and correctively performed.	**Functional Safety Assessment (FSA 1)**	WSP	LJ	- FSA 1 Check List	- FSA 1 Report	To be verified	LJ

Realisation Period										
4	Design and Engineering (Note 3)	Clause 11, 12 & 13	To design the SIS to meet the requirements for SIF and their associated safety integrity **NOTE:** This activity is OUTSIDE the scope of WSP. Typically, covered by others (e.g. the SIS Supplier) activities and their own procedures.	**1. Particular attention will be paid to the following** **2. Typical design issues to be considered are** **3. Application software**	iconsys	JS	- Tata 70057533-56-URS-0001 BPCS and SIS URS	- iconsys Functional Design Specification Benzole FDS	To be verified	TR
							- Tata 70057533-56-SRS-0001 Safety Requirement Specification	- iconsys 215029-BPCS-LD - Loop Diagrams	To be verified	TR
							- Tata 70057533-53-0007 Benzole Storage C&E	- iconsys 215029-RCP - Electrical Schematics	To be verified	TR
							- Tata 70057533-53-2103 P&ID Benzole Storage Tanks			
							- Tata 70057533-53-2104 P&ID Benzole Loading And Effluent Pump			
							- Tata 70057533-53-2105 P&ID Benzole Tanker Loading			
							- Tata 70057533-53-REP-0001 Tank Venting First Issue			
							- Tata 70057533-56-SRS-0001 Safety Requirement Specification			
							- Tata FSA Level #1			
10	Functional Safety Assessment - Stage 2	5.2.6.1 of Clause 5	To investigate the evidences through the independent cross-check and arrive at a judgement on the functional safety achieved by the SIS, it assess that: - no safety requirements are missed out, - all SIFs are functional correctly by SIS, and - all documentation review and FAT activities have been effectively and correctively performed.	**Functional Safety Assessment (FSA 2)**	iconsys	JS	- iconsys Functional Design Specification Benzole FDS	- FSA 2 Report	To be assessed	TR
							- iconsys 215029-BPCS-LD - Loop Diagrams			TR
							- iconsys 215029-RCP - Electrical Schematics			TR
5	Installation, Commissioning and Validation	Clause 14 & 15	1. To install, test and commission the SIS 2. To validate that the SIS meets in all respects the requirements for safety in terms of the required SIF and their associated safety integrity **NOTE:** This activity is OUTSIDE the scope of WSP. Typically, covered by others (e.g. the Client) activities and their own procedures.	**Installation and Validation**	Iconsys / C&P / Tata	Project team	70057533-56-SPC-0001 E,C&I Installation Specification (by WSP)	- Inspection, Testing and Calibration Certificates - Red-lined drawings	To be verified	CS
				FAT/SAT and Pre-commissioning	iconsys	JS	Safety FAT/SAT Plans	- Safety FAT/SAT Reports	To be assessed	TR
										TR
				Commissioning	Tata / Iconsys	Project team		- Acceptance Certificate	To be verified	CS
10	Functional Safety Assessment - Stage 3	5.2.6.1 of Clause 5	To investigate the evidences through the independent cross-check and arrive at a judgement on the functional safety achieved by the SIS after installation and commissioning, it assess that: - safety requirements are met, - safety requirements per se are correct, and - other review/check activities (including verification, FS audit and validation) have been effectively and correctively performed. **NOTE:** This activity is OUTSIDE the scope of WSP. Typically, covered by others (e.g. the Client) activities and their own procedures.	**Functional Safety Assessment (FSA 3)**	Tata	JH		- FSA 3 Report	To be assessed	LJ

Operations Period										
6	Operations and Maintenance	Clause 16	1. To ensure that the functional safety of the SIS is maintained during operation and maintenance **NOTE:** This activity is OUTSIDE the scope of WSP. Typically, covered by others (e.g. the Client) activities and their own procedures.	**Operations and Maintenance**	Tata	TBC			To be verified	JH
10	Functional Safety Assessment - Stage 4	5.2.6.1 of Clause 5	To investigate the evidences through the independent cross-check and arrive at a judgement on the functional safety maintained by the SIS and process hazards being managed during operation peroid , it assess that: - safety requirements are met, - safety requirements per se are correct, and - other review/check activities (e.g. proof-test, etc.) have been effectively and correctively performed. **NOTE:** This activity is OUTSIDE the scope of WSP. Typically, covered by others (e.g. the Client) activities and their own procedures.	**Functional Safety Assessment (FSA 4)**	Tata	JH		- FSA 4 Report	To be assessed	N/A
7	Modifications (Note 4)	Clause 17	To make corrections, enhancements or adaptations to the SIS, ensuring that the required SIL is achieved and maintained. **NOTE:** This activity is OUTSIDE the scope of WSP. Typically, covered by others (e.g. the Client) activities and their own procedures.	**Modifications**	Tata	TBC			To be verified	TBC
					TBC	TBC			To be verified	TBC
					TBC	TBC			To be verified	TBC
10	Functional Safety Assessment - Stage 5	5.2.6.1 of Clause 5	To investigate the evidences through the independent cross-check and arrive at a judgement on the functional safety achieved by the SIS after modifications, it assess that: - safety requirements are met, - safety requirements per se are correct, and - other review/check activities (e.g. impact analysis, modification request procedure, etc.) have been effectively and correctively performed. **NOTE:** This activity is OUTSIDE the scope of WSP. Typically, covered by others (e.g. the Client) activities and their own procedures.	**Functional Safety Assessment (FSA 5)**	TBC	TBC		- FSA 5 Report	To be assessed	N/A
8	Decommissioning	Clause 18	To ensure proper review, sector organisation, and ensure SIF remains appropriate NOTE: This activity is OUTSIDE the scope of WSP. Typically, covered by others (e.g. the Client) activities and their own procedures.	**Decommissioning**	Tata	TBC			To be verified	TBC
					TBC	TBC			To be verified	TBC
					TBC	TBC			To be verified	TBC

Appendix 11 – TSUK FSMS 001 competence

Competence RACI

Functional Safety Work Activity	Work Activity Description	Subject Matter Expert SME	FS Engineer	FS Manager	Plant Operations	Plant Maintenance	Process Safety	Procurement	Human Resources
1	Hazard and Risk Assessment	C	C	A	C	C	R	_	_
2	Allocation of Safety Functions to protection layers	C	C	A	C,I	C	R	_	_
3	Safety Requirements Specifications for the SIS	I,C	C,R	A	_	_	C	_	_
4	Design and Engineering of SIS	I,C	C,R	A	_	_	I	_	_
5	Installation, Commissioning and Validation	I,C	C,R	A	I	C	I	_	_
6	Operation	I,C	C,R	A	R, C	I	I,C	_	_
6	Maintenance	I,C	C,R	A	I	R, C	I,C	A	_
7	Modification	I,C	C,R	A	I	C	I,C	_	_
8	Decommissioning	I,C	C,R	A	I	I	I,C	_	_
9	Verification	R	C,R	A	_	_	R		_
10	Management of functional safety	I,R	C,R	A	R	R	R	A	C, R, I
10	Functional Safety Assessment and Auditing	R	C,R	A, C	C	C	I,C	_	C, R, I
11	Safety Lifecycle Structure and Planning (all phases)	I,C	C,R	A	I	I	R	_	_

Competence definitions

Work Activity	SLC Activity	Awareness	Practitioner	Expert
1	Hazard and Risk Analysis	Awareness training of 61511 '- Understand where Hazard Identification fits into BS EN 61511 Functional Safety - Awareness of the HAZOP methodology - Experience of the process	- Understands principles of Hazard Identification, Hazard analysis and HAZOP studies. - Understands where hazards may be introduced by the SIS. - Understands the Process - Has Experience of participating in Hazard Identification, Hazard analysis or HAZOP studies. - Formal Training & sign off by the business to lead Hazard and Risk Assessment (FS PS only)	- Formally trained or extensive experience eg. (+10 HAZOPs) in the principles of Hazard Identification, Hazard analysis and HAZOP studies. -Can challenge the quality of the HAZOP process - Can challenge where hazards may be introduced by the SIS. - Awareness of the Process
2	Allocation of Safety Functions to protection layers	Awareness training of 61511 '- Understand where Allocation of Safety Functions fits into safety lifecycle/project (explains why) - Understanding of different types of protection layers. - Awareness of SIL determination methodology - Experience of the process	- Understands the effectiveness of different types of protection layers. - Formal training or experience of allocating safety functions to protection layers. - Has experience of participating in and can challenge SIL determination. - Is familiar with use of SIL determination software, if appropriate. - Formal Training & sign off by the business to lead Hazard and Risk Assessment (FS PS only)	-Understands the effectiveness of different types of protection layers. -Formally trained or extensive experience of allocating safety functions to protection layers. -Can challenge the quality of SIL determination. -Is familiar with use of SIL determination software, if appropriate.
3	Safety Requirements Specifications for the SIS	Awareness training of 61511 -Understand where Safety Requirements Specification fits into the lifecycle -Has technical competence in the relevant technologies associated with the process	-Knows and understands how to develop functional specifications. - Has technical competence in the relevant technologies associated with the process and SIS. -Knows and understands how to develop integrity specifications. -Has experience of developing role statements and functional and integrity specifications for SIS.	-Has experience in developing several functional specifications for SIS. - Has technical competence in the relevant technologies associated with the process and SIS. -Knows and understands how to develop integrity specifications. - Has the authority to sign off a Safety Requirements Specification for SIS -Has experience of developing role statements/definition of the SIS and functional and integrity specifications for SIS.
4	Design and Engineering of SIS	N/A	-Knows and understands how to select the most appropriate sensors and final elements to meet the safety requirements. -Knows and understands how to select an appropriate logic solver to meet the safety requirements. -Has experience of selecting sensors and final elements for SIS applications at the required SILs. -Has experience of specifying a logic solver for SIS application at the required SILs. -Has experience of configuring a logic solver for SIS application at the required SILs. -Has experience of performing and challenging SIL verification (reliability analysis) calculations. -Has experience of integrating and factory testing a logic solver to meet specified functional requirements. -Has experience of developing documentation for SIS including factory and Site Acceptance Test procedures. - Formal training in Functional Safety - Has technical competence in the relevant technologies associated with the process and SIS. - Can Challenge on technical aspects of documentation related to the Design and Engineering of SIS.	-Knows and understands how to select the most appropriate sensors and final elements to meet the safety requirements. -Knows and understands how to select an appropriate logic solver to meet the safety requirements. -Has experience of selecting sensors and final elements for SIS applications at the required SILs. -Has experience of specifying a logic solver for SIS application at the required SILs. -Has experience of configuring a logic solver for SIS application at the required SILs. -Has experience of performing and challenging SIL verification (reliability analysis) calculations. -Has experience of integrating and factory testing a logic solver to meet specified functional requirements. -Has experience of developing documentation for SIS including factory and Site Acceptance Test procedures. - Formal training and experience in Functional Safety - Has technical competence in the relevant technologies associated with the process and SIS. - Can Challenge on technical aspects of documentation related to the Design and Engineering of SIS. - Has authority to Sign off approval of the Dossier for Design and Engineering of SIS.

Work Activity	SLC Activity	Awareness	Practitioner	Expert
5	Installation, Commissioning and Validation	- Technical competance in the field within which they are working. - Awareness training of functional safety 61511 - Familiarity with installation and commissioning issues with SIS field equipment and logic solvers. - Familiarity with Site Acceptance Testing issues with SIS field equipment and logic solvers. - Familiarity with site installation of SIS equipment and systems. - Has been involved with site commissioning and acceptance testing activities against test procedures for SIS. - Familiarity with test activities and commissioning test procedures - Knows and understands company's commissioning procedure	- Familiarity with installation and commissioning issues with SIS field equipment and logic solvers. - Familiarity with Site Acceptance Testing issues with SIS field equipment and logic solvers. - Has been involved with site installation of SIS equipment and systems. - Has been involved with site commissioning and acceptance testing activities against test procedures for SIS. - Familiarity with test activities and commissioning test procedures - Knows and understands company's commissioning procedure - Familiar with the details of IEC 61508 and IEC 61511 and their application to the process sector.	- Knows and understands installation and commissioning issues with SIS field equipment and logic solvers. - Knows and understands Site Acceptance Testing issues with SIS field equipment and logic solvers. - Has managed site installation of SIS equipment and systems. - Has managed site commissioning and acceptance testing activities against test procedures for SIS. - Experience and authority to define, evaluate and challenge acceptance test activities and commissioning test procedures - Knows and understands company's commissioning procedure - Knows and undertands the details of IEC 61508 and IEC 61511 and their application to the process sector.
6	Operation	N/A	- Knows and understands how to undetake Safety Instrumented Systems (SIS) operations to ensure functional and integrity requirements are achieved. - Knows and understands procedures for responding to SIS activation. - Awareness training of functional safety 61511 - Knowledge and experience of the process and associated failure modes.	- Knows and understands how to manage SIS operations to ensure functional and integrity requirements are achieved. - Has developed or familiar with procedures for responding to SIS activation. - Knows and understands the procedural controls for management of overrides and inhibits. - Awareness training of functional safety 61511 - Knowledge and experience of the process and associated failure modes.
7	Maintenance	- Awareness training of functional safety 61511	- Knows and understands how to undertake SIS maintenance to ensure functional and integrity requirements are achieved. - Knows and understands procedures for maintenance and proof testing of SIS. - Carries out maintenance and proof testing and submits results to ensure that functional and integrity requirements are achieved - Knows and understands procedural controls for management of overrides and inhibits. - Awareness training of functional safety 61511 - Knowledge and experience of the process and associated failure modes.	- Knows and understands how to manage SIS maintenance to ensure functional and integrity requirements are achieved. - Knows and understands procedures for maintenance and proof testing of SIS. - Has reviewed testing results to ensure that functional and integrity requirements are achieved and amended testing scopes and test intervals as necessary. - Knows and understands procedural controls for management of overrides and inhibits. - Awareness training of functional safety 61511 - Knowledge and experience of the process and associated failure modes.

Appendix 12 – TSUK functional safety policy

3 Functional Safety Policy
3.1 Policy Statement

TATA Steel UK is committed to prevent any incident from harming the people who work for us, our visitors, our neighbours and the environment. We will achieve this by understanding the nature of the risks from our assets/processes and engineer them to ensure safety and integrity. This means making sure our assets are well designed, thoroughly inspected, maintained and safely operated. Functional Safety and Safety Instrumented Systems SIS are a core contributor to achieving this policy.

3.2 Scope

This standard provides requirements for management activities to be applied to all stages of the development and use of SIS to reduce process risks to tolerable levels.

Management activities include risk analysis, planning, competence, selection, design, verification, implementation, modification and independent functional safety assessment of SIS.

This standard addresses SIS that are based on the use of Electrical, Electronic and Programmable Electronic (E/E/PE) technology. The same basic principles of this standard apply to SIS logic solvers that are based entirely on other technologies (e.g., pneumatic or hydraulic). This standard also addresses the SIS sensors and final elements regardless of the technology used.

This standard applies to all SIS safety lifecycle phases.
Evaluation and communication

Evaluation of achievement of this policy will be conducted via 3rd Party Functional Safety Audit.

The standard shall be disseminated throughout the organisation via the business Directors and their direct sub-ordinates.

4 Functional Safety Strategy
4.1 General

Management of the safety lifecycle shall comply with IEC 61511.

The strategy approach, detailed in accordance with IEC 61511-1 lifecycle, for the development and usage of an SIS shall adhere to the following stages:

Efforts shall be made for new & existing facilities to produce an inherently safer design that minimises hazards and reliance on protective systems, including SIS.
Major Accident Hazards shall be identified, analysed and severity stated in accordance with TATA Steel Europe Process Safety Principle 3 – Hazard Identification and its supporting documentation.

The identified hazard, according to the severity level shall be subject to Layers Of Protection Analysis LOPA to determine the event frequency, mitigated event frequency and also to determine further required risk reduction (if any), the LOPA shall identify the Safety Instrumented Function SIF, Probability of Failure on Demand Average PFD_{avg} or Probability of Dangerous Failures per Hour PFH and Safety Integrity Level SIL in accordance with TATA Steel Europe Process Safety Principle 3 – Hazard Identification and its supporting documentation.
Safety requirements specification and detailed requirements for SIF, SIS, Basic Process Control Systems BPCS, Instrumented Alarm Functions IAF and other means of risk reduction credited in LOPA shall be developed in accordance with this standard.
SIS, BPCS and IAF credited with Risk Reduction against Major Accident Hazards in LOPA shall be designed, installed, validated, and commissioned in accordance with this standard.
Lifecycle operation and maintenance requirements shall be performed in accordance with Section 6.8
Modifications shall be implemented in accordance with Section 6.

Relationships between relevant standards in the safety lifecycle shall be referenced in accordance with this document.

4.2 Evaluation and communication

Evaluation of achievement of this strategy will be conducted via competent 3rd Party Functional Safety Audit.

The standard shall be disseminated throughout the organisation via the business Directors and their direct sub-ordinates.

4.3 Review

The policy and strategy shall be reviewed periodically (5 yearly).

4.4 Strategy achievement

The target date for achieving the strategy is 2024.

4.5 Deviations from strategy

Any deviation from the strategy and procedures as laid out in this functional safety management system shall be explicitly agreed with the Functional Safety Subject Matter Experts, Manager Process Engineering & Directors (Engineering & Operational).

5.3 Verification (Phase 9)
General

A summary table listing verification activities with their measures/techniques, persons responsible, inputs, outputs, dates and non-conformance requirements is given in TSUK FSMS 005 verification plan requirements. TSUK FSMS 005 shall be utilised for verification planning or an alternative agreed method if verification is being carried out by a competent third-party consultant. TSUK FSMS 005 shall be incorporated into a wider detailed documented safety plan.

For installed SIS, the appointed Works Area Functional Safety Engineer/s in their local area shall develop and implement a verification plan that identifies for each lifecycle phase, the measures/techniques, persons responsible, inputs, outputs, dates and non-conformance requirements.

For new projects, the appointed Functional Safety Engineer/s shall develop and implement a verification plan that identifies for each lifecycle phase, the measures/techniques, persons responsible, inputs, outputs, dates and non-conformance requirements.

The purpose of the verification process is to demonstrate by independent review, analysis and/or testing that the required outputs satisfy the defined requirements for the appropriate life-cycle phases as identified by the verification planning.

Verification planning shall be carried out throughout the SIS safety life cycle and shall define all activities required for the appropriate life-cycle phase including application programming. Verification planning shall conform to IEC 61511 by addressing the following:

The verification activities.
The procedures, measures and techniques to be used for verification including implementation and resolution of resulting recommendations.
When these activities will take place.
The persons, departments and organisations responsible for these activities, including levels of independence.
Identification of items to be verified.
Identification of the information against which the verification is carried out.
The adequacy of the outputs against the requirements for that phase.
Correctness of the data:
How to handle non-conformances
Tools and supporting analysis.
The completeness of the SIS implementation and the traceability of the requirements.
The readability and auditability of the documentation.
The testability of the design

Where the verification includes testing, the verification planning shall also address the following.

The strategy for integration of application program and hardware and field devices, including the integration of sub-systems that shall comply with other standards (such as machinery or burner).
Test scope (describes the test set-up and what type of test to be performed including the hardware application programming and programming devices to be included.
Test cases and test data (these will be specific scenarios with the associated data).
Types of tests to be performed.
Test environments including tools, hardware, all software and required configuration.
Test criteria (pas or fail) on which the results of the test will be evaluated.

Procedures for corrective action on failure of a test.
Physical location.
Dependence on external functionality.
Appropriate personnel.
Management of change.
Non-conformances.

It is generally expected that verification that includes testing with respect to application program and hardware and field devices will be managed by competent third-party systems integrators. The verification process shall be reviewed and checked by the Functional Safety Engineer (Works Area or Projects).

Non-safety functions integrated with safety functions shall be verified for non-interference with the safety functions.

Verification shall be performed according to the verification planning.

8 Functional Safety Competence

Objective

In order to comply with IEC 61511 TATA Steel Management will ensure that the necessary organisational structure and procedures are in place to implement the requirements of the standard.

All persons, departments or other organisations (including contractors and sub-contractors) having responsibility for functional safety of SIS shall be identified and informed of the responsibilities assigned to them.

Persons, departments and other organisations having responsibility for functional safety of SIS shall be competent.

Functional Safety Competence Management System FSCMS

The FSCMS has been developed in line with HSE Managing competence for safety-related systems and EEMUA 222.

TSUK FSMS 001 has been developed as follows:

Functional Safety work activities within the scope of the CMS are defined.
The work activities to be performed by an individual are grouped into a role and RACI (responsible, accountable, consulted, informed) assigned.
Every role has competence criteria specified according to the essential work activities and competence levels set (Awareness, Practitioner & Expert).
Every role has a competence assessment template.
Individuals are assigned to a role and assessed against the relevant competence criteria utilising the competence assessment template.
On completion of the competence assessment a conclusion will be made on the competence achieved by the individual. The conclusion will result in one of the following outcomes: *Fully competent to fulfil the competence requirements of the role,*

Competent to fulfil the role with gaps that can be successfully managed or *not competent to fulfil the role at present.*

An individual's competence assessment will take place on appointment of role and periodically.

Appendix 13 – Proposed FSMP

High level view of requirements and resources

Clauses of BS EN 61511-1	Clause 10	5.2.6.1 of Clause 5	Clause 11, 12 & 13	5.2.6.1 of Clause 5	Clause 14 & 15					5.2.6.1 of Clause 5	Clause 16	5.2.6.1 of Clause 5	Clause 17	5.2.6.1 of Clause 5	Clause 18
Tasks to be Carried out	**Safety Requirement Specifications (SRS)**	**Functional Safety Assessment (FSA 1)**	**1. Particular attention will be paid to the following**	**Functional Safety Assessment (FSA 2)**	**FAT**	**Installation**	**Cold Commissioning including procedure**	**Proof Test**	**Hot commissioning & SAT including procedure**	**Functional Safety Assessment (FSA 3)**	**Operations and Maintenance**	**Functional Safety Assessment (FSA 4)**	**Modifications**	**Functional Safety Assessment (FSA 5)**	**Decommissioning**
Orgnisations Responsible for activities	**System integrator**	**Designer**	**System Integrator**	**System Integrator**	**System integrator**	**EC&I Contractor**	**Tata**	**System integrator**	**Tata**	**Tata**	**Tata**	**Tata**	**Tata**	**Tata**	**Tata**
Persons Responsible for activities	System integrator Engineer (1)	Tata Process Safety Engineer (1)	System integrator Engineer (1)	System integrator Engineer (1)	System integrator Engineer (1)	Tata projects E,C & I Engineer (1)	Tata projects E,C & I Engineer (1)	System integrator Engineer (1)	Tata projects E,C & I Engineer (1)	Tata Process Safety Engineer (1)	Tata Operations (1)	Tata Process Safety Engineer (1)	Tata Operations (1)	Tata Process Safety Engineer (1)	Tata Operations (1)
Verifier	System integrator Engineer (2)	Tata Process Safety Engineer (2)	System integrator Engineer (2)	System integrator Engineer (2)	System integrator Manager (1)	Tata projects E,C & I Engineer (2)	Tata projects E,C & I Engineer (2)	Tata projects E,C & I Engineer (1)	Tata projects E,C & I Engineer (2)	Tata Process Safety Engineer (2)	Tata Process Safety Engineer (1)	Tata Process Safety Engineer (2)	Tata Process Safety Engineer (1)	Tata Process Safety Engineer (2)	Tata Process Safety Engineer (1)
Independence	Must not have had any inlvolvement with writing the SRS	Must not have been involved in FSA1 assessment	Must not have been involved in the SIS development	Must not have been involved in FSA2 assessment	Not involved in creating FAT procedure	Not involved in the installation process	Not involved in commsiioning activities	Not involved in creating procedure	Not involved in creating procedure	Must not have been involved in FSA3 assessment	Not involved in day to day site activities	Must not have been involved in FSA4 assessment	Not involved in day to day site activities	Must not have been involved in FSA5 assessment	Not involved in day to day site activities
Acceptence	**Tata Project Manager (1)**	**Tata Project Manager (1)**	**Tata Project Manager (1)**	**Tata Process safety Engineer (1)**	**Tata Operations (1)**	**Tata Project Manager (1)**	**Tata Operations (1)**	**Tata Operations (1)**	**Tata Operations (1)**	**Tata Operations (1)**	**Tata Operations (1)**	**Tata Operations (1)**	**Tata Operations (1)**	**Tata Operations (1)**	**Tata Operations (1)**
Validator	N/A	N/A	N/A	N/A	Tata Project Lead Engineer (1)	N/A	N/A	N/A	Tata Project Lead Engineer (1)	N/A	N/A	N/A	N/A	N/A	N/A
Verifier (of the validation task)	N/A	N/A	N/A	N/A	Tata Project Manager (1)	N/A	N/A	N/A	Tata Project Manager (1)	N/A	N/A	N/A	N/A	N/A	N/A
Verifier Independence	N/A	N/A	N/A	N/A	Not involved in FAT procedure	N/A	N/A	N/A	Not involved in SAT procedure	N/A	N/A	N/A	N/A	N/A	N/A

Simplified resource requirements for functional safety project

Resource Requirements	
Tata	
Tata Process Safety Engineer	2
Tata Project Manager	1
Tata Project Lead Engineer	1
Tata projects E,C & I Engineer	2
Tata Operations	1
Contractor	
System integrator Engineer	1
System integrator Manager	1

Examples of detailed requirements for safety lifecycle elements 1, 3 and 5

SLC Phase	1		
SLC Avctivities	Hazard and Risk Assessment		
Clauses of BS EN 61511-1	Clause 8		
Activity Purpose/Objectives	To determine the hazards and hazardous events of the process and associated equipment, the sequence of events leading to the hazardous event, the process risks associated with the hazardous event, the requirements for risk reduction and the safety functions required to achieve the necessary risk reduction. Typically, HAZOP is employed in this phase.		
Tasks to be Carried out	**HAZOP** • A description of each parameter deviation and cause • Consequences of the deviation • Existing safeguards • Actions required		
Orgnisations Responsible for activities	Tata		
Persons Responsible for activities	Process Safety Engineer (Chairperson)		
Competence	Formal Training	Trained in conducting HAZOP Studies	
	Experience	Minimum 3 years experience In Hazop Studies	
	Demonstration of Knowledge	Minimum 1 peer reviewed Hazop Sudy in last 5 years	
		DMS Ref:	**Rev No.**
Inputs/Documentation	HAZOP template		
	Basis of Safety		
	HS2		
	Basis of Design		
	Control Philosophy (URS)		
	BPCS Interlocks		
	SIS Interlocks		
	C_E Schedule		
	Alarm List		
	Functional Safety Description		
	DSEAR HAC Zoning Plan		
	DSEAR HAC Zoning Elevation		
	Final HAC Report		
	Related HAZOP Studies		
	P&ID		
Outputs/Evidence	HS3 Document		
Verifier	Process Safety Engineer		
Competence	Formal Training	Trained in HAZOP Studies	
	Experience	Minimum 3 years experience In Hazop Studies	
	Demonstration of Knowledge	Minimum 1 peer reviewed Hazop Sudy in last 5 years	
Independence	Must not have been involved in HAZOP		
Acceptence	Tata Project Manager		

SLC Phases	3		
SLC Avctivities	Safety Requirement Specifications		
Clauses of BS EN 61511-1	Clause 10		
Activity Purpose/Objectives	To specify the requirements for each SIS, in terms of the required SIF and their associated safety integrity, in		
Tasks to be Carried out	**Safety Requirement Specifications (SRS)**		
Orgnisations Responsible for activities	System integrator		
Persons Responsible for activities	System integrator Engineer		
Competence	**Formal Training**	TUV 61508 / 61511 Functional Safety Trained	
	Experience	Minimum 3 years experience writing SRS	
	Demonstration of Knowledge	Minimum 1 SRS verified by 3rd party in last 5 years	
		DMS Ref:	**Rev No.**
	LOPA Worksheet		
	LOPA Report		
	Trip & Interlock Schedule		
Inputs/Documentation	Updated P&IDs		
Outputs/Evidence	SRS		
	SIL-rated Instrument Datasheets		
Verifier	System integrator Engineer		
Competence	**Formal Training**	TUV 61508 / 61511 Functional Safety Trained	
	Experience	Minimum 3 years experience wrting SRS	
	Demonstration of Knowledge	Minimum 1 SRS verified by 3rd party in last 5 years	
Independence	Must not have had any inlvolvement with writing the SRS		
Acceptence	Tata Project Manager		

SLC Phase		5						
SLC Avctivities		Installation, Commissioning and Validation						
Clauses of BS EN 61511-1		Clause 14 & 15						
Activity Purpose/Objectives		1. To install, test and commission the SIS						
Tasks to be Carried out		**FAT**	**Installation**	**Cold commissioning procedure**	**Cold Commissioning**	**Proof Test**	**Hot commissioning procedure**	**Hot Commissioning / SAT**
Orgnisations Responsible for activities		System integrator	EC&I Contractor	Tata	Tata	System integrator	Tata	Tata
Persons Responsible for activities		System integrator engineer	EC&I Contractor	EC&I Contractor	EC&I Contractor	System integrator engineer	EC&I Contractor	Tata projects E,C & I Engineer
Competence	Formal Training	TUV 61508 / 61511 Functional Safety	Compex 1-4	TUV 61508 / 61511 Functional Safety	TUV 61508 / 61511 Functional Safety	TUV 61508 / 61511 Functional Safety	TUV 61508 / 61511 Functional Safety	TUV 61508 / 61511 Functional Safety
	Experience	Minimum 3 years experience in FAT	Minimum 3 years experience in Atex area installation	Minimum 3 years experience in plant commissioning	Minimum 3 years experience in plant commissioning	Minimum 3 years experience in conducting proof tests	Minimum 3 years experience in plant commissioning	Minimum 3 years experience in plant commissioning
	Demonstration of Knowledge	Minimum 1 FAT Document peer reviewed in last 5 years	Compex 1-4	TUV 61508 / 61511 Functional Safety Exam passed	TUV 61508 / 61511 Functional Safety Exam passed	TUV 61508 / 61511 Functional Safety Exam passed	TUV 61508 / 61511 Functional Safety Exam passed	TUV 61508 / 61511 Functional Safety Exam passed
Inputs / Documentation		FAT Plan SRS FDS Rev No	E,C&I Installation Specification Rev No	SRS FDS Rev No	Cold Commissioning procedure Rev No	SIF Proof test procedure Rev No	Completed cold Commissioning procedure Snagging list SRS FDS Rev No	Hot Commissioning procedure Rev No
Outputs/Evidence		Signed FAT test document Snagging register	Inspection, Testing and Calibration Certificates Atex Inspections Red-lined drawings	Cold Commissioning procedure	Completed cold commissioning document Snagging registor	Signed proof test document by tester and witness	Hot Commissioning procedure	Completed Hot commissioning document Snagging registor
Verifier		System integrator Manager	EC&I Contract manager	System integrator Engineer	Tata Project Lead Engineer or Project Manager	Tata projects E,C & I Engineer	System integrator Manager	Tata Project Lead Engineer or Project Manager
Competence	Formal Training	TUV 61508 / 61511 Functional Safety	Compex 14	TUV 61508 / 61511 Functional Safety	TUV 61508 / 61511 Functional Safety	TUV 61508 / 61511 Functional Safety	TUV 61508 / 61511 Functional Safety	TUV 61508 / 61511 Functional Safety
	Experience	Minimum 3 years experience in FAT	Minimum 3 years experience in Atex	Minimum 3 years experience in plant	Minimum 3 years experience in plant	Minimum 3 years experience in plant	Minimum 3 years experience in plant	Minimum 3 years experience in plant
	Demonstration of Knowledge	Minimum 1 FAT Document peer reviewed in last 5 years	Compex 14	TUV 61508 / 61511 Functional Safety Exam passed	TUV 61508 / 61511 Functional Safety Exam passed	TUV 61508 / 61511 Functional Safety Exam passed	TUV 61508 / 61511 Functional Safety Exam passed	TUV 61508 / 61511 Functional Safety Exam passed
Independence		Not involved in creating FAT procedure	Not involved in the installation process	Not involved in creating procedure	Not involved in commsiioning activities	Not involved in creating procedure	Not involved in creating procedure	Not involved in the Hot Commissioning / SAT activities
Acceptence		Tata Operations	Tata Project Lead Engineer or Project Manager	Tata Project Lead Engineer or Project Manager	Tata Operations	Tata Operations	Tata Operations	Tata Operations
Validator		Tata Project Lead Engineer	N/A	N/A	N/A	N/A	N/A	System integrator Engineer
Verifier (of the validation task)		Tata Project Manager						System integrator Manager
Verifier Independence		Not involved in FAT procedure						Not involved in the Hot Commissioning / SAT activities

Safety Lifecycle element five after modification

SLC Phase		5									
SLC Avctivities		Installation, Commissioning and Validation									
Clauses of BS EN 61511-1		Clause 14 & 15									
Activity Purpose/Objectives		1. To install, test and commission the SIS									
Tasks to be Carried out		**FAT**		**Installation**		**Cold Commissioning inc procedure**		**Proof Test**		**Hot commissioning SAT and procedure**	
Orgnisations Responsible for activities		System integrator		EC&I Contractor		Tata		System integrator		Tata	
Persons Responsible for activities		System integrator engineer		EC&I Contractor		EC&I Contractor		System integrator engineer		EC&I Contractor	
Competence	Formal Training	TUV 61508 / 61511 Functional Safety		Compex 1-4		TUV 61508 / 61511 Functional Safety		TUV 61508 / 61511 Functional Safety		TUV 61508 / 61511 Functional Safety	
	Experience	Minimum 3 years experience in FAT		Minimum 3 years experience in Atex area installation		Minimum 3 years experience in plant commissioning		Minimum 3 years experience in conducting proof tests		Minimum 3 years experience in plant commissioning	
	Demonstration of Knowledge	Minimum 1 FAT Document peer reviewed in last 5 years		Compex 1-4		TUV 61508 / 61511 Functional Safety Exam passed		TUV 61508 / 61511 Functional Safety Exam passed		TUV 61508 / 61511 Functional Safety Exam passed	
Inputs / Documentation		FAT Plan SRS FDS	Rev No	E,C&I Installation Specification	Rev No	SRS FDS Cold Commissioning procedure	Rev No	SIF Proof test procedure	Rev No	Completed cold Commissioning procedure Snagging list SRS FDS Hot Commissioning procedure	Rev No
Outputs/Evidence		Signed FAT test document Snagging register		Inspection, Testing and Calibration Certificates Atex Inspections Red-lined drawings		Completed cold commissioning document Snagging registor		Signed proof test document by tester and witness		Completed Hot commissioning document Snagging registor	
Verifier		System integrator Manager		EC&I Contract manager		Tata Project Lead Engineer or Project Manager		Tata projects E,C & I Engineer		Tata Project Lead Engineer or Project Manager	
Competence	Formal Training	TUV 61508 / 61511 Functional Safety		Compex 14		TUV 61508 / 61511 Functional Safety		TUV 61508 / 61511 Functional Safety		TUV 61508 / 61511 Functional Safety	
	Experience	Minimum 3 years experience in FAT		Minimum 3 years experience in Atex		Minimum 3 years experience in plant		Minimum 3 years experience in plant		Minimum 3 years experience in plant	
	Demonstration of Knowledge	Minimum 1 FAT Document peer reviewed in last 5 years		Compex 14		TUV 61508 / 61511 Functional Safety Exam passed		TUV 61508 / 61511 Functional Safety Exam passed		TUV 61508 / 61511 Functional Safety Exam passed	
Independence		Not involved in creating FAT procedure		Not involved in the installation process		Not involved in commsiioning activities		Not involved in creating procedure		Not involved in creating procedure	
Acceptence		Tata Operations		Tata Project Lead Engineer or Project Manager		Tata Operations		Tata Operations		Tata Operations	
Validator		System Integrator Engineer		N/A		N/A		N/A		System Integrator Engineer	
Verifier (of the validation task)		Tata Project Manager								Tata Project Manager	
Verifier Independence		Not involved in FAT procedure								Not involved in SAT procedure	

Appendix 14 – Dissertation timeline

Dissertation Timeline											2024				
Paul Boxer		M	J	J	A	S	O	N	D	J	F	M	A	M	Comments
Planning															
Review research proposal aims and objectives	Low Risk														
Review timetable from research Proposal	Low Risk														
Carry out background reading	Low Risk														
Christmas Break	Goal														
Update and Review dissertation timeline	Med Risk														Key points to check progress
Literature Review															
Main literature Review	High Risk														Risk of over reading
Summer Holiday	Goal														2 weeks florida
Final literature review	Low Risk														
Dissertation															
Compile Report	On Track														
Meet With Tutor to discuss project	Low Risk														15 hrs spread over 6 months
Complete dissertation	Milestone														
Final dissertation review	Goal														Grammer, spelling etc
Week Break from dissertation	Low Risk														
Final Final dissertation review	Goal														
Submit Dissertation	Milestone														Plan to hand in End March
Complete Viva	Milestone														Viva due May 2024
Data collection															
Send out Questionaires	Low Risk														
Complete interviews	Low Risk														Depending on availability
Project	Med Risk														Risk if project completion is delayed - FMSP should be created upfront
Project Review	High Risk														include interview with Projects process safety engineer
Data collection from project & Questionaire	High Risk														Risk if project completion dealyed or Questionnaires not returned
Data analysis	Low Risk														