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ASSET OPERATIONAL READINESS ASSESSMENT OF NEW BUILD POWER PLANT EQUIPMENT

By

Thokozani Michael Nkosi

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Full names of student: **Thokozani Michael Nkosi**

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1. ABSTRACT

The delivery of medium and mega project has been a challenge for a number of decades, with attempts made to reduce the associated issues around engineering projects implementation. Project delivery before 1950 mainly relates to cost, time, and scope, with a lack of documentation pertaining to methods, as well as inadequate techniques to achieve a quality final product. The concept of Asset Operational Readiness (AOR) emanates in the 1950s from the military as means of providing the “developmental state of weapons systems”. The concept gained momentum as it was associated with “system safety” in the 1980s for decision-making.

AOR can be defined as an establishment of a state or configuration which, after completion of the project, “places the right people in the right places at a right time working with the right hardware according to the right procedures and management controls”.

The research work covered in this thesis, aims to propose a best-practice AOR framework for mega-projects in the power generation industry. A thorough Literature Review provides an overview of best practices on the AOR requirements for various industrial fields. The survey shows that AOR implementation follows the Project Life Cycle Management (PLCM) principles, from conceptual and pre-feasibility phases to commissioning and operation phases. In addition, the survey considers methodologies and techniques, which aids to enhance AOR framework development such as Root Cause Analysis (RCA) exercises.

The study has provided an opportunity to develop an AOR theoretical framework refinement methodology, inclusive of RCA, AOR assessment tools, qualitative survey tool, and scoring systems. The AOR best practice framework and refinement methodology application to a real mega project case study, with historical data, enables a stage wise assessment of each component for individualized performance rating. This provides an identification of the areas that require refinement to have an improved AOR framework as outcome.

The research outcome shows that there are implications for inadequate development and implementation of items in the proposed framework. The implications range from rework during manufacturing and construction, poor product quality delivery, poor performance post commissioning, and overall cost overruns. In addition, the study provides evidence that implementation of the AOR framework aids a project to realize its potential and yield positive results, which ultimately benefits an organization in terms of quality product delivery, cost reduction, and optimal Operations and Maintenance of the established asset.

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2. ABBREVIATION AND DEFINITION

AOR	Asset Operation Readiness
AS&R	Asset Strategy & Review
CAD	Computer Aided Design
CMMS	Computerized Maintenance Management System
CQM	Construction Quality Manual
DEA	Department of Environmental Affairs
DOE	Department of Energy
DoL	Department of Labour
DRP	Design Review Procedure
EIA	Environmental Impact Assessment
EN	European Standards
EPRI	Electrical Power Research Institute
FAT	Factory Acceptance Test
FD	Forced Draught
FG	Flue Gas
FGD	Flue Gas Desulphurization
FIDIC	The International Federation of Consulting Engineers: international standards Organization for the consulting engineering & construction
FMEA	Failure, Mode, and Effects Analysis
FMECA	Failure, Mode, Criticality and Effects Analysis
GACS	Gap Analysis Case Study
HAZOP	Hazard and Operability Study
HDR	Handover Design Report
HO	Handover
ID	Induced Draught
IDR	Integrated Design Review
IRL	Integration Readiness Level
ISO	International Organization of Standards
ITP	Inspection and Test Plan
KPI	Key Performance Indicator

LC	Life Cycle
LCC	Life Cycle Cost
MCR	Maximum Continuous Rating
MPS	Mill Pulverization System
MRL	Manufacturing Readiness Level
NDT	Non-Destructive Testing
NEMA	National Environmental Management Act
NIST	National Institute of Standards and Technology
O&M	Operations and Maintenance
OEM	Original Equipment Manufacturer
OR	Operational Readiness
PA	Primary Air
PF	Pulverized Fuel
PJFF	Pulse Jet Fabric Filter
PLCM	Project Life Cycle Management
PQM	Project Quality Manual
QCP	Quality Control Plan
RACI	Responsibility, Accountability, Consultation, and Informed
RAM	Reliability Availability Maintainability
RAMS	Reliability Availability Maintenance System
RBI	Risk Based Inspection
RBI	Risk Based Inspection
RCA	Root Cause Analysis
RCM	Reliability Centered Maintenance
RH1	Boiler Steam generator Re-heater 1
RMS	Reliability Management System
RPR	Rapid Problem Resolution
RRL	Reliability Readiness Level
SAP	Systems Applications and Products in data Processing
SGE	Steam Generator Effectiveness
SHE	Safety, Health, and Environment
SHEQ	Safety, Health, Environment, and Quality

SO_2	Sulphur dioxide
SO_x	Sulphur Oxides
SPO	Self-Paced Online Handover and Design Data Management system
SRL	System Readiness Level
SwRL	Software Readiness Level
TPM	Total Production Maintenance
TRL	Technology Readiness Level
UCLF	Unplanned Capacity Loss Factor
URS	User Requirement Specification
US	United State

3. INTRODUCTION

The delivery of medium and mega project has been a challenge for a number of decades, with attempts made to reduce the associated issues around engineering projects implementation timelines and effectiveness (Krauss, 2014). Project delivery before 1950 mainly related to cost, time, and scope, with a lack of documentation pertaining to methods, as well as inadequate techniques to achieve quality final product (Seymour & Hussein, 2014).

The concept of Asset Operational Readiness (AOR) emanated in the 1950s from military to give the “developmental state of weapons systems” (Kingston-Howlett, et al., 2016). The concept gained momentum as it was associated with “system safety” in the 1980s and used to influence decision making in corporate environment (Kingston-Howlett, et al., 2016).

Asset Operational Readiness (AOR) can be defined as an establishment of a state or configuration which “places the right people in the right places at a right time working with the right hardware according to the right procedures and management controls” (Nertney, 1987). The expectation is that the environment is psychological and physically conducive and functional inclined to allow success (Kingston-Howlett, et al., 2016).

During the decades of progressive investment towards project delivery improvement, Asset Operational Readiness (AOR) Frameworks were some of the proposed tools to assist eliminating challenges faced in mega projects (Krauss, 2014). The study conducted by National Institute of Standard and Technology (NIST) (National Institute of Standards and Technology, 2006) reveals that for United State; only 30 percent mega project have been successfully delivered on projected timelines and cost. The low percentage of successful project delivery remains a concern in modern projects as it has been over 3 to 4 decade of engineering project implementation, indicating the need for further work aimed at improving AOR frameworks.

The failure of project delivery has been due to a number of factors outlined in various research studies. The challenges which were revealed by Kraus (Krauss, 2014) and others relate to lack of experience in areas pertaining to AOR, as well as assurance

thereof to effectively and efficiently deliver a project. In addition, modern projects have become more sophisticated to deliver, inducing challenges not only limited to AOR technical aspect, but also inclusive of non-technical factors such as internal and external stakeholder relationship management.

In a drive to improve AOR in projects, Nertney (Nertney, 1987) and Gerbec (Gerbec, 2017) detailed frameworks which show the elements of AOR that need to be considered in a project. The intent of AOR unlike project management, does not focus on the project delivery time and budget, but rather focuses on the state (Operability and Maintainability of Asset) of the end-product as the project transitions from Construction to Operations and Maintenance (O&M). AOR framework aforementioned is a process which aids the design and execution team, such that, there is a smooth transition during project handover of the end-product to the client by ensuring that there is a constant self-examination of deliverables (Krauss, 2014).

There are various AOR frameworks which were developed to achieve a smooth transition as aforementioned and these include; AOR throughout PLCM, competency factors, risk management plan, and system engineering for people, software, and system interface.

AOR as a process or framework is applicable to medium and mega project environment such as capital project, refurbishment projects, and so forth. The AOR framework possible utilization includes; energy sector, mining industries, process industries, and so forth. The applicability of AOR as outlined by Nertney (Nertney, 1987), Gerbec (Gerbec, 2017), and (Krauss, 2014) gives birth to this research study to address the challenges as detailed below. The problem statement provides a basis for further study on the topic of AOR to aid the engineering and science field in optimizing AOR framework.

3.1. Research Study Problem Statement

Engineering asset project development has experienced concerns on asset maintainability and reliability, which emanates from complexity to deliver and maintain advancing technology. The approach used to drive three project elements (i.e. cost, time and budget) and overlooking AOR role has resulted in challenges with

the Operations and Maintenance (O&M) of the Engineering Assets post commercial operation (Seymour & Hussein, 2014).

Project development challenges include but not limited to; under-specification particularly on contract technical & commercial gaps, technical documentation, spare parts equipment, engineering models, construction works, maintenance strategies, and so forth. In addition, there are numerous design defects, product quality issues, and ultimate overall asset reliability issues during Operations and Maintenance (O&M) which are evident of challenges pertaining to AOR in a project.

The aforementioned challenges and gaps with existing AOR theory, have led to the present study, purposed to outline an industrial best practice (AOR) framework. The Framework will assist by ensuring that the necessary processes are followed during the PLCM in order to deliver project (new and refurbishment) to a user, which can be maintained and operated in a sustainable manner, for medium and mega engineering projects.

The research study aimed at detailing well-defined best practice AOR framework will be beneficial to ensuring realization of the following:

- The Integrated multi-disciplinary AOR framework provides guidelines for various organizations, and in the field of engineering and science, to enhance the project delivery in accordance with the specification. In addition, the Framework ensures that the equipment is ready for Operations and Maintenance (O&M).
- The GACS conducted might be able to assist with identification of gaps associated with project delivery. The gaps identified will have possible solutions, recommendations, and mitigating measures as means of ensuring successful project delivery.
- The engineering asset developed or constructed by an organization benefits from the research study, as the study will provide mitigation measures to most of the regular occurrences.
- Detailed preventative guidelines in accordance with world best practice to ensure quality product delivery. The guidelines apply to current projects and might extend to future new developments.

The listed points could ensure that there are reduced failures on the specific items selected for case studies, and ensure readiness to operate and maintain. In addition, the study serves as a guide applicable to unique assets in ensuring optimal performance during operation with high asset availability while having a reduced numbers of unplanned shutdown and premature failures.

3.2. Research Study Approach

The research study covers literature on AOR frameworks in capital engineering, network railways industry, and mining and oil Industry, which later forms a good basis for development of sound integrated AOR framework. The Integrated AOR framework is applicable to medium and mega green field projects, refurbishment projects, and expansion projects sector.

The theoretical research information obtained through various organizations and sectors highlighted above aids to detail AOR framework components for each stage in PLCM.

The key AOR categories which are considered to achieve a smooth transition from design and construction to Operations and Maintenance (O&M) includes; AOR execution strategy, AOR support (competency, tool, and software), Computerized Maintenance Management System (CMMS), risk mitigation strategy, and maintenance strategy.

The outcome of the theoretical AOR framework will undergo validation to ensure that the model is practical and can yield positive result when implemented in capital projects. The validation involves the use of several AOR framework refinery methods highlighted below:

- Gap Analysis Case Study (GACS) conducted from mega capital project equipment assists to validate capability of the Framework, as well as to identifying areas of concerns, which require attention.
- A multi-technique Root Cause Analysis (RCA) used to enhancement the proposed multi-disciplinary AOR framework. The RCA application will be on a selected GACS as part of improving the AOR framework.

- The qualitative survey conducted through the candidates participating in the selected mega capital project, to further the understanding of challenges with AOR development and implementation.
- The AOR framework Assessment tool used to conduct GACS supports an embedded scoring system to provide indication in terms of confidence with the AOR implementation during the PLCM.

The next sub-section gives a high-level preview of the holistic structure for the AOR research study.

3.3. Research Study High-level Preview

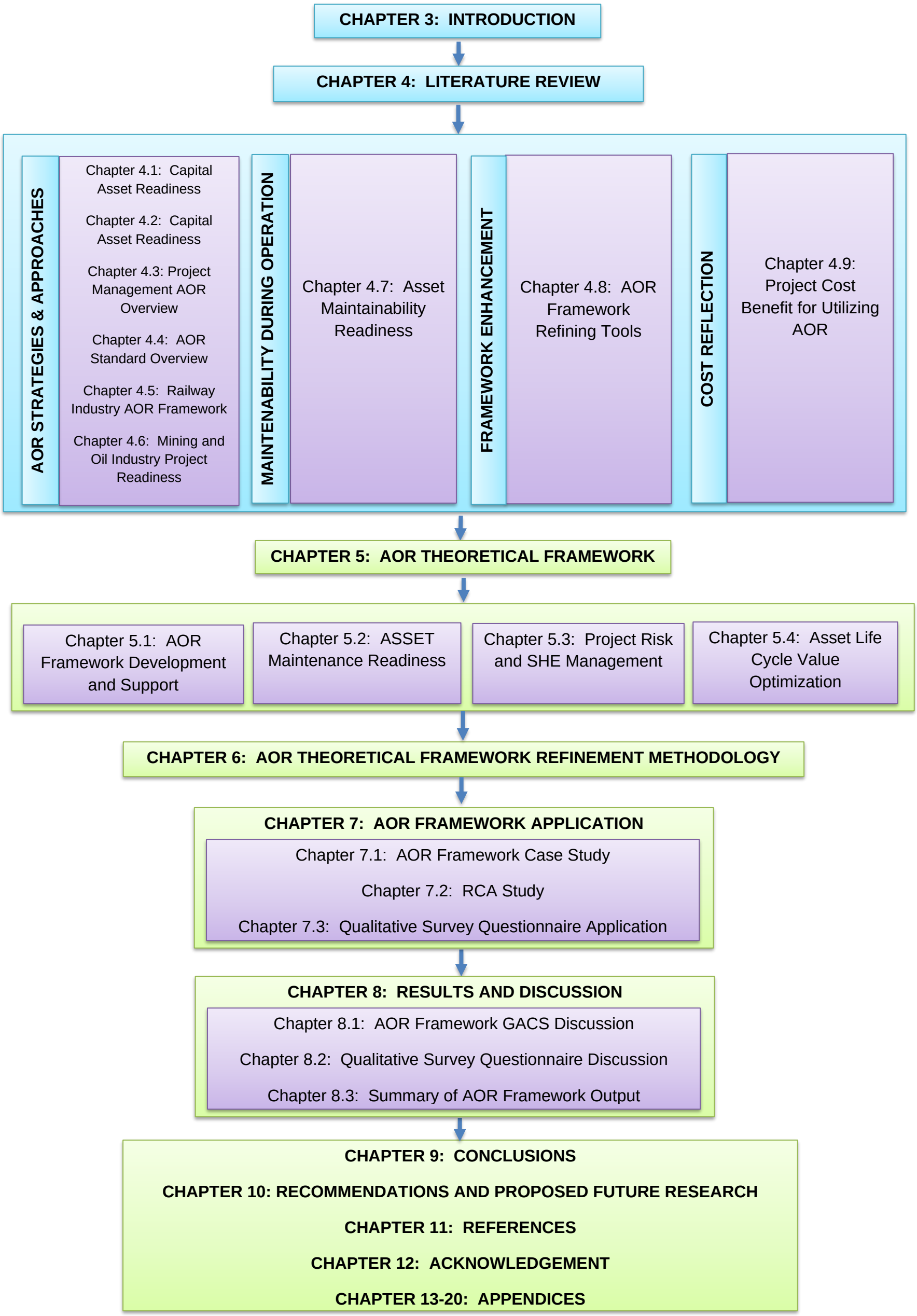

Figure 1: AOR research study high-level preview.

4. LITERATURE REVIEW

AOR is one of the vital elements in Project Life Cycle Management (PLCM) as it is the area, which ensures that the resources, right training, spare equipment, consumables, licenses, and right information is in place prior to Operations and Maintenance (O&M) of the asset.

The need to carry out the world's best practice AOR in various industrial sectors such as nuclear, processing plant, renewables, oil industry, and so forth, gets triggered by the business' objectives of ensuring that the organizational value chain, is sustains and yield the required outcome in terms of the project life costing and asset utilization.

This section explores AOR frameworks detailed on several research studies as well as approaches from various sectors. The sectors explored in this section are essential to understand the components necessary to establish a best practice AOR framework.

4.1. AOR Framework Requirements and Considerations

AOR has become essential for all types of industries, and this is evident with the challenges various industries face during Operations and Maintenance (O&M) stage. The challenges experienced by Engineering Asset projects narrow down to complex project execution and integration in line with the business objectives, goals, and compliance to regulatory requirements (Seymour & Hussein, 2014).

4.1.1. AOR Framework Optimization Considerations

The challenges arising from complex project execution and integration require a well-structured AOR framework, which ensures a sustained Asset life during O&M phase. The literature assessed provides justification of the extent to which AOR can be of significance use to alleviate aforementioned challenges.

The following are areas to consider as means of achieving an optimized AOR framework in a project environment (US Department of Energy, 2010):

- Do the planning at the right time during the PLCM. Planning takes place in the design phase with the aid of all relevant stakeholders to alleviate unforeseen circumstances at successive stages.
- Develop O&M strategies and procedures as part of proactive approach during the early stages of the project, and include the non-conformance management.
- Ensure that there are procedures, which cover every element of the project to provide confidence of the state of as-build documentation before Asset handover.
- Ensure that there is capacity with relevant competence and skills, to design, implement, commission, and operate and maintain, the asset.
- Ensure that there is training programs, and training department which aims at developing skill-sets within the Organization. The O&M team must be ready to operate and maintain the asset once commissioned.
- Ensure that engineers, managers, inspectors, operators are accountable for their work as part of a control measure for incompetency on performing tasks.

4.1.2. Industrial Implementation requirements

Implementation of AOR is required for the following project types in any industry (US Department of Energy, 2010):

- New facilities: This includes extension of Organization's infrastructure, and other new projects such as new build Power Plants.
- Significant modification of infrastructure initiated by the business needs to improve the current setup.
- Plant maintenance required due to planned and unplanned shutdowns.
- Shutdown of plant or system due to unsafe operation conditions which can result on catastrophic failure or fatalities.

According to the PLCM shown on Figure 2 , it is important to understand that for any asset; maintainability, availability, and operational readiness is essential for the success of the project as well as the final product delivery (Kececioglu, 2003).

AOR is a concept intended to quantify the probability that a system will be at the required performance level when the need arises for it to operate its function. Hence, during the development stages it is required that the asset has all the necessary attributes required for ensuring that there is high availability and reliability to enhance the productivity.

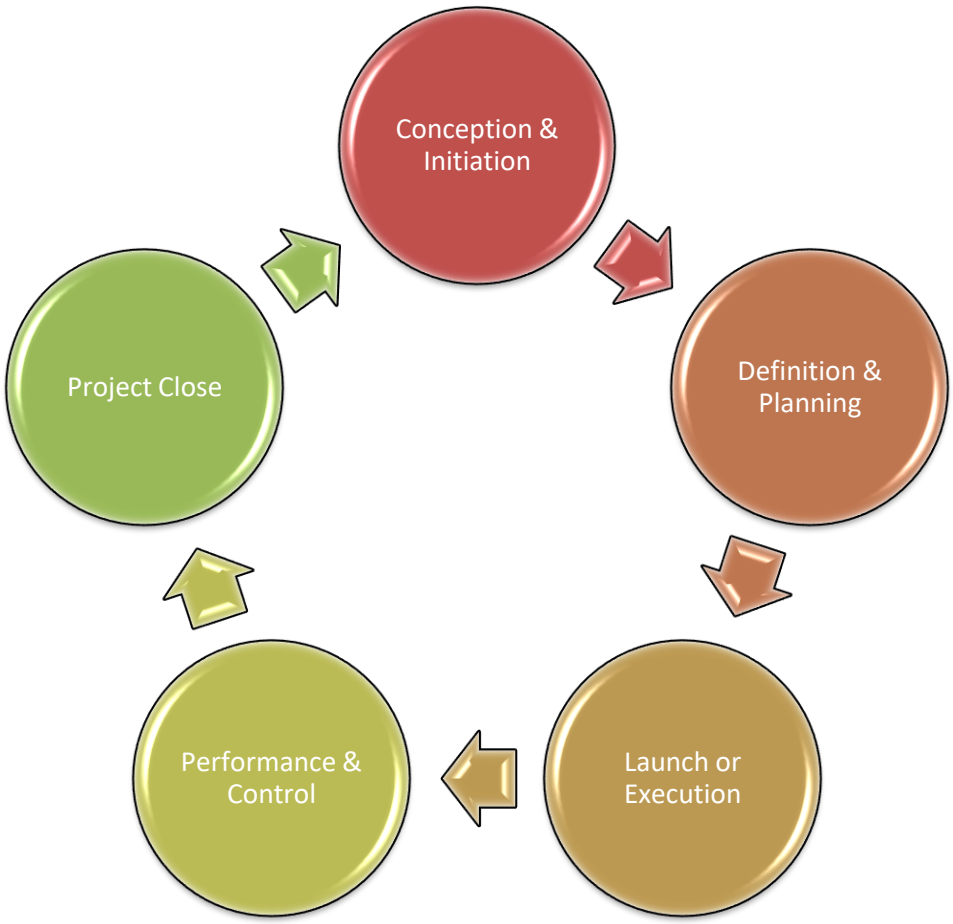

Figure 2: Project Life Cycle Management that indicates the AOR phases.

The AOR is not a standalone process, and needs to take into account reliability mission and adequacy of the design detail, so that the system is effective. In addition, this aids with Asset achieving its mission, functionality, and design intent during Operations and Maintenance (O&M) phase.

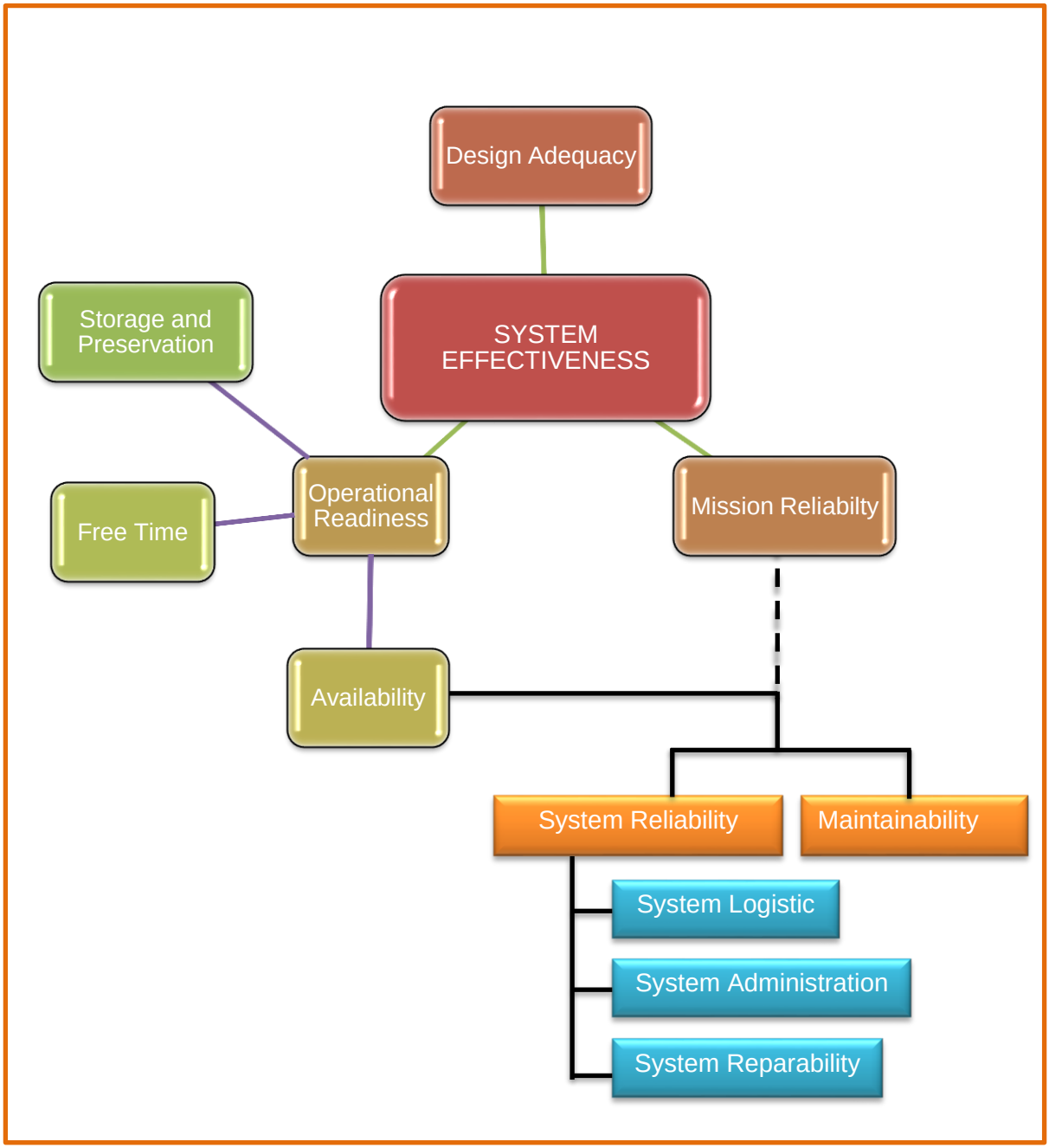

Figure 3: Schematic of a system effective structure which show the AOR, reproduced (Kececioglu, 2003).

Figure 3 depicts the role of operational readiness to ensure system effectiveness. This is applicable to all types of engineering systems in various industries. The system expectation is to satisfy the desired state when required, by ensuring that, within the operating philosophy there is. In addition, the expectation also requires that there is “free time” which entails the system is operationally ready even when

not required, “storage time” which acts as backup or spares, and “operating time” which is the time the system is in operation. The expectation provides confidence that the Asset is operationally ready to fulfil design intent.

Figure 3 also shows that the system will require repair, spare components, and any other related administrative time in other to restore the state of the system for operation. This is in line with the maintainability strategy developed during the early stages of the system life cycle.

4.1.3. AOR Framework Modelling Systematic Methodology

There are several methods which can be used to model a well-defined AOR structure, which can assist to eliminate failures that emanate from construction and planning phase, and ultimately impacting Operations and Maintenance (O&M). The typical methodology which is discussed by (Jahnig & Agoston, 2016) gives a systematic approach to a sound AOR strategy.

The **initial stage** of the methodology involves developing and establishing the readiness assessment structure. The structure will comprise of the following:

- The Organizations’ operating model requires clear guidelines and understanding by all personnel.
- Ensure that the AOR assessment factors incorporate personnel, procedures and processes, as well as the system or environment.
- Clear alignment and assessment of activities and project type.

The **next stage** involves conducting an assessment at the necessary stages of the project including the planning phase. This stage must include the following:

- Data acquisition for preliminary AOR assessment to ensure that there is information to baseline the implementation.
- Conduct an evaluation of the information to identify the gaps and issues associated.
- Prioritize AOR gaps based on the risk assessment analysis conducted.

The **third stage** is to ensure that there is proper management to close the AOR identified gaps and this must take cognisance of the following:

- AOR governance and reporting structures are required as part of mitigation measures.
- Management of the activities and execution plan, there is clear responsibility matrix, and the risks have a management structure.
- Progress and activities requires monitoring.

4.1.4. AOR Framework Alignment Success Factors

The integration of methodology aforementioned into a PLCM reduces misalignment during implementation, and ensures successful project implementation with the correct process and procedures. The alignment consideration includes the following (Jahnig & Agoston, 2016):

- The AOR program should align with the activities of the project, and this entails synergy throughout the project.
- The market aspect, supply chain, and equipment require assessment as means of enhancing AOR activities.
- The AOR assessment should include the interrelationship between the personnel, hardware or system, and the processes associated.

4.2. Capital Assets Readiness

In many capital projects, one of the observed critical phases in a project is during commissioning and ramp-up periods, as this is a stage, which plays a crucial role for assessing the performance of the newly build asset(s). An article which aims to discuss operation readiness gaps between O&M and Construction for new build capital projects (DiStefano, et al., 2018), shows that approximately 30 percent of the investments or project value is wasted during this period (commissioning and ramp-up).

The ramp-up stage shown on Figure 4 takes place after conclusion of commissioning phase, and the aim is to ensure Asset performs optimal, and challenges during the O&M stage are alleviated.

The optimization stage tends to have major issues due to instability and prolonged downtime, which contribute negatively to the revenue and profitability of the Asset. The poor decisions and oversight made on the early stages have consequences of poor performance of the Asset, and this is due to lack of documentation, poor specification and design documentation, lack of skills and competences, and inadequate O&M philosophy. In addition, the aforementioned relates to failure of system engineering process within a project.

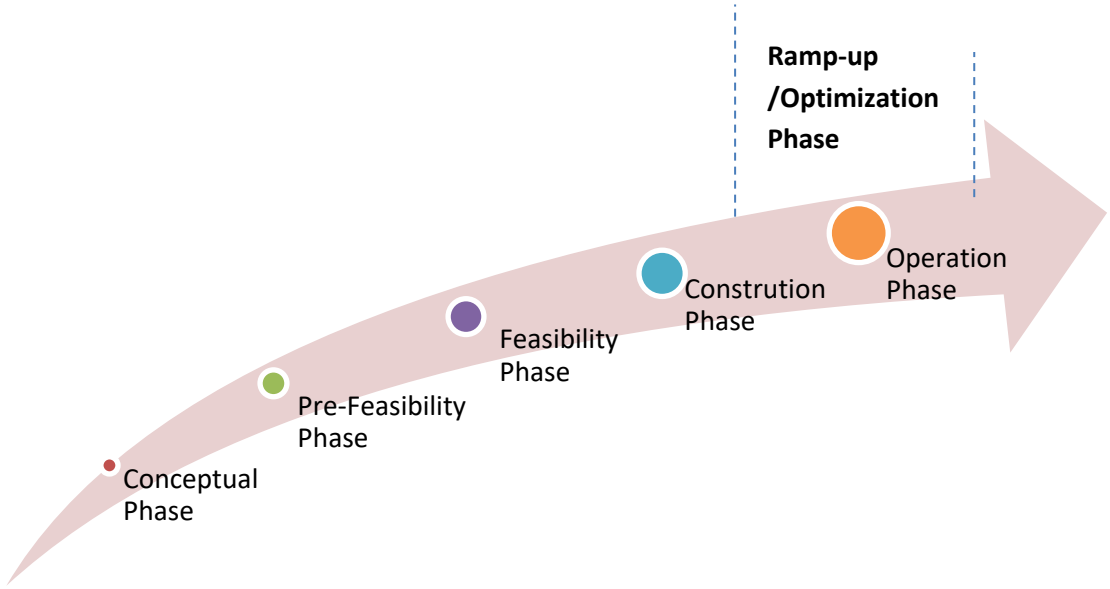

Figure 4: Project life cycle with the ramp-up optimization phase (DiStefano, et al., 2018).

There are several benefits with deploying an AOR framework discussed by (Christison, 2017) which narrows down to the following points:

- A well-defined AOR plan will have information, which provides right answers to the risks and questions posed during preparatory, and handover stage of a PLCM. This also assists to minimize the value leakages during the project stages.

- AOR enables an environment conducive for achieving milestones set in a project schedule and business case.
- There is an improved capability and knowledge from the project team, which arise from multidisciplinary interaction and involvement in the preparatory stages. This also includes lesson learned and knowledge acquired from training.

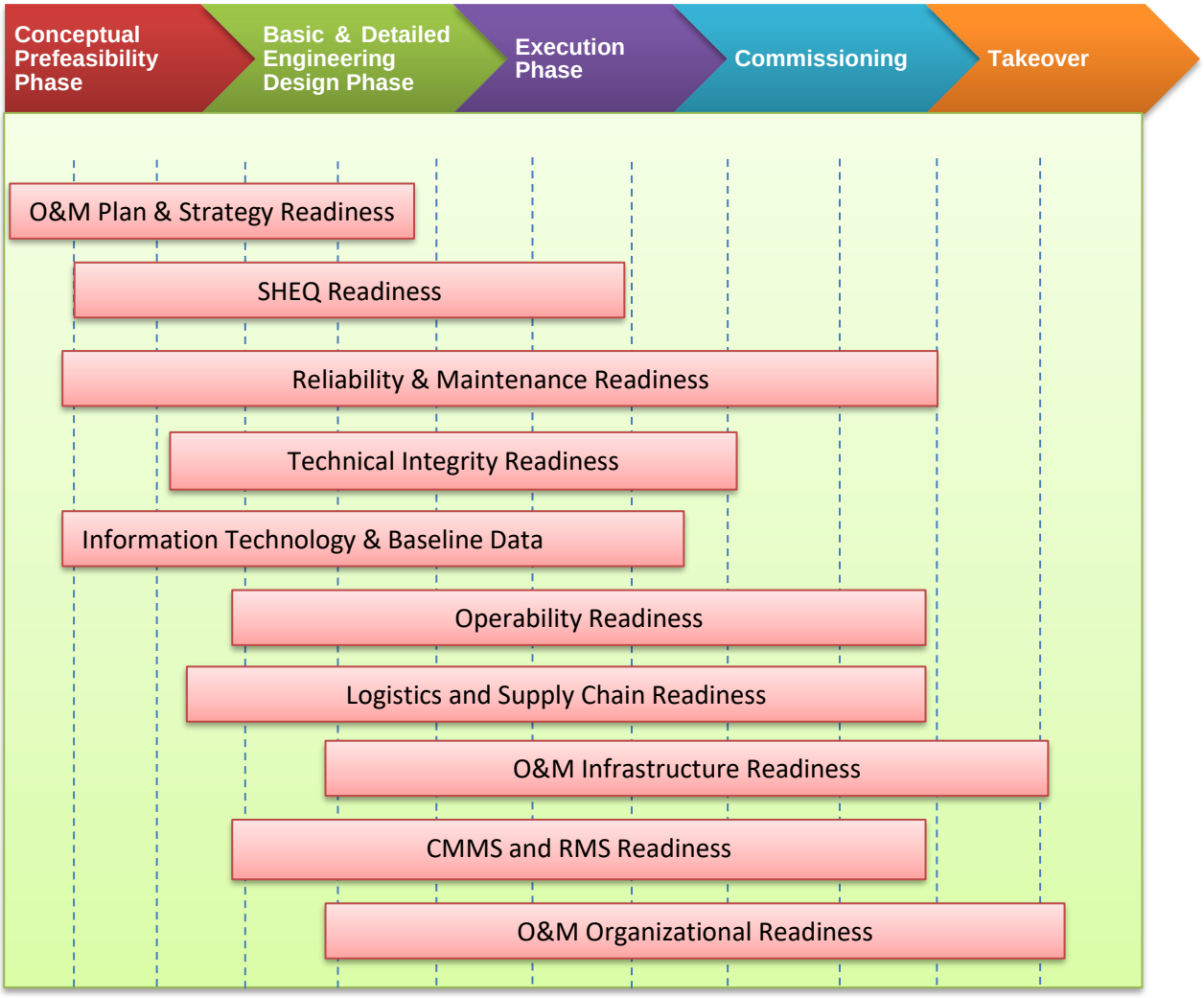

Figure 5: Operation Readiness Capital Project model, reproduced (DiStefano, et al., 2018).

- There are also benefits in terms of SHEQ, definition of commissioning timelines, clear resourcing and staffing, and elimination of unnecessary hurdles which might hamper smooth transition between commissioning and system optimization. The teams deployed to address issues pertaining to AOR framework have a mandate of helping the capital project to realize value.

There are measures in a PLCM to avoid challenges when operating an Asset, which have the potential to a reduced maintenance cost, and are as follows (Christison, 2017):

- The transition between design, construction, commissioning, and operation is catered for and integrated to meet the requirements.
- The Operations and Maintenance (O&M) team are granted an opportunity as stakeholders to contribute to the design, equipment selection, procurement strategies, and commissioning of the asset(s).
- The Organization should not put pressure on the O&M team to perform less maintenance as means of improving production targets impacted by the construction team delays.

There are mitigating measures for the points listed above which are in line with a well-organized development and execution system. Figure 5 above shows a Project Life Cycle Management (PLCM), which has various Asset Readiness elements at a particular phase of the project (Christison, 2017). There are several AOR elements in a PLCM, which require attention to ensure that activities execution is in line with the mandate of the business, to deliver an operationally ready end-product.

The phases highlighted in Figure 4 as well as components of Figure 5 give a robust program, which can aid to address risks associated with the Asset O&M. The risk mitigation measures will require adherence to all elements through the design and construction phase of the project. The main items incorporated in an AOR framework include but not limited to Asset data capturing, maintenance strategy such as FMECA (Failure, Mode, Effects, and Criticality Analysis), condition based strategies, risk and maintenance management system, as well as skills and competency training.

4.2.1. Operational Readiness of Physical Assets

The section covers the physical Asset examples, which includes an electricity production plant as well as an electricity transmission network. The principles from these examples would also apply to other sectors, although not considered here.

4.2.1.1. Generator Operational Readiness

There are several preparatory activities, which lead to sound AOR. These activities are important as they supplement the more intensive portion of operation readiness activities, which occur in the start of the construction as shown on the figure below Figure 6.

In practice, there are events, which cause variation on the roles and responsibilities of the team, and this calls for integration of activities as part of management support. Figure 6 illustrates the PLCM Overlap with operational readiness activities. AOR assists to integrate all development and construction activities with the plant start-up requirements. Items that need to be considered for Asset turn-over are as follows (Gardner, 2001):

- The unit or system must have defined criteria for acceptance, and clear guide on closing of punch line items. The compliance permit for environmental consideration must form part of the key elements.

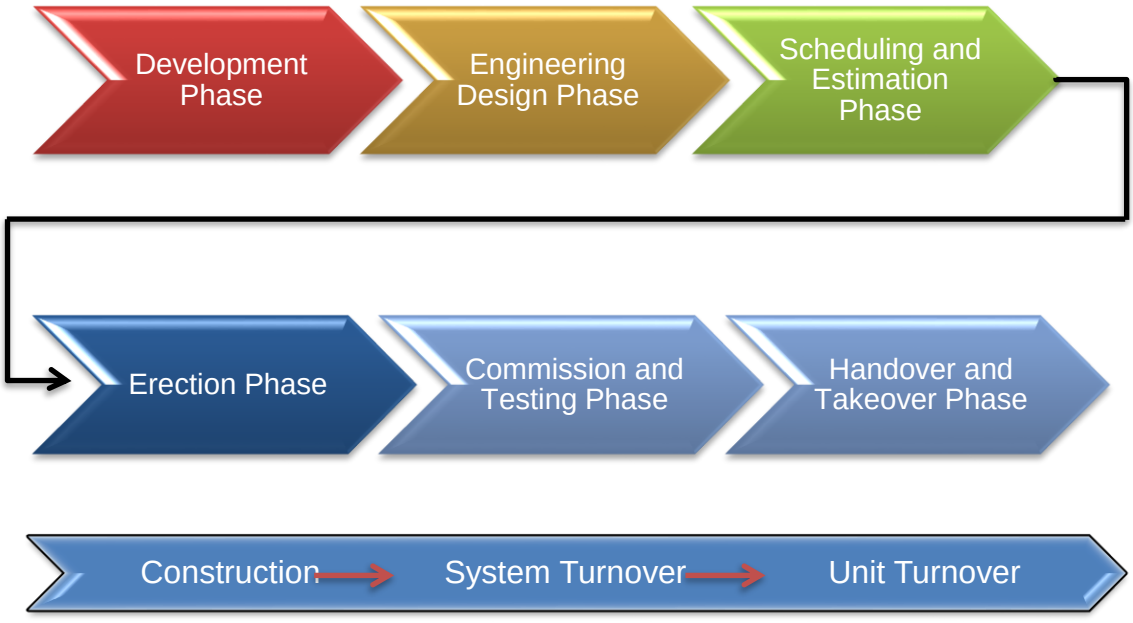

Figure 6: Life Cycle model with the Asset handover key stages, reproduced (Gardner, 2001).

- The system start-up procedures development needs to align with specific system or area.

- The adopted contract must have a clear guide on what to deliver.
- The personnel involved at any stage of the project need to have training as means of addressing issues of skills and competency.

The AOR is a critical aspect of ensuring that there is proper control of the product delivered, and independence is of paramount importance as means of assuring that there is objective and impartial assessment required for successful asset readiness (Jacobi, 2009). The adopted contract will have specifications for unit start-up, turnover, and approval of the plant. The plant will have a warrantee and warrantee period as stipulated by the employer's contractor, and that will cover defect(s) which arise from operating the plant.

Warrantees do not provide sufficient assurance for correction of plant latent defects post asset handed over, as there are challenges, which the client encounters, such as contractors claiming that a failure was due to client or operators' negligence (Jacobi, 2009).

4.2.1.2. Generic Transmission Infrastructure Readiness

Smart Grid technology is an essential role player within the electricity supply industry and can assist to alleviate incapability to deal with the complexity of the grid system (Tugurlan, et al., 2011). The need to move towards the smart grid technology is due to the benefit thereof, to integrate the electricity grid system, complexity intelligence, and computer technology. The benefit also aligns with the need to include the green energy in the grid in a stable and sustainable manner.

The smart grid software technology readiness discussed by (Tugurlan, et al., 2011) shows that there are significant areas to consider which include; basic mathematical model, applicability of the concept, system analysis, integration, as well as implementation of the concept in order to have a technology which can be integrated to the end-product.

4.2.2. Pilko AOR Overview for Capital Projects

Pilko is one of the Organizations which invested time to understand the industrial key areas which include; operability, environmental, safety risk, and health. The paper, which has been, published deals with transition of new build capital project to reliable commercialized assets. The paper discusses some of the key elements of AOR, which caters for; value chain, operational risk, and incident benefit, as means of effective and efficient delivery of a project (Richter, 2018). The five key elements are as follows:

- The first area to detail in a successful AOR model, relates to Organizational vision alignment to the Asset acquisition. The design, implementation, and planning team must take cognisance of the benefit of maximizing the output, as well as lowering the associated cost during execution stage. The vision communication and integration to all key departments and stakeholders is of paramount importance.

- The project needs to have key performance measures, which align with the business model for operations. A best-practice measuring model requires historical events and other international experiences, to ensure a well-defined metric structure.

- The operations plan communication to every personnel taking part in a project ensures synergy for all activities in the PLCM. The sequencing of activities and resources optimization will play a vital role in the implementation phase, and reduce unexpected costs to the project.

- The right detail is required for deliverables of a project as this has major contribution to the success or failure of a project. The deliverables such as the maintenance philosophy, commissioning procedures, performance procedures, operation strategy, and so forth, must be one of the major considerations.

- Consistent communication in a project is one of the key elements to enhance a culture of continuous alignment with Business vision. This is to ascertain if the project delivery aligns with the plans and fulfils regulations requirements.

4.2.2.1. AOR Key Success Drivers

There are drivers for AOR in any project such as capital project, modification or retrofitting, or other interventions, and a specific team needs to be deployed to ensure that there is alignment between implementation and Business governance and procedure (Richter, 2018).

The team responsible for AOR implementation should close all gaps from planning phase to the handover phase. It should be noted that the intervention of an AOR team will perform reviews during idea creation, conceptualization and detailed engineering design, as a front-end activity to provide assurance that the deliverables from the engineering team are on track, and are executed within the correct stage of the PLCM. This will aid in delivery of a safe and high-quality final-product to the client (Richter, 2018).

4.2.2.2. AOR Process Components

The starting point for AOR modelling is to understand the role of developing and baselining an integrated AOR review process. This enables stabilization and assists to streamline operations requirement within shorter timelines, which in essence, becomes vital to the delivery of a seamless product.

The AOR review requires systems and processes which includes; personnel competency, SHE model, supply chain readiness, safety, automation and incident prevention model, hazard analysis, commissioning and start-up processes, operations readiness on takeover, and risk mitigation plans (Richter, 2018).

The aforementioned process and system areas are of great importance as they have an ability to influence the success of project delivery. The secondary element to consider is the management or leadership support to enable the AOR team to play the role required. The leadership needs to provide adequate oversight throughout the project (Richter, 2018).

4.2.2.3. Benefit for Improved AOR Model

There are several benefits for implementing a well-defined AOR model, which has the minimum requirement for success. The aforementioned systems and processes will provide assurance on the following (Richter, 2018):

- Reduce risks during operation from well-executed implementation plan, commercialization of the Asset on the planned time, Asset delivery in a safe and reliable manner, time reduction to avoid material degradation and compromised quality.
- Ensuring that the quality, plant standard, and maintainability of the Asset is as per the user requirements.
- Ensure alignment of project drives with project deliverables through an integrated and well-implemented AOR review processes and reporting methodologies.

4.3. Project Management AOR Overview

AOR is one of the major areas in a project to aid in providing the necessary assurance, and in many instances, there is a perception that is an activity, which needs to take place on the final stages of implementation as a pre-commissioning or commissioning measure. In modern times AOR has been understood as one of the integral elements for Asset delivery, which needs to be considered, as it acts as preventative measure to failure of a project. There are considerations that AOR has a risk management activity in a PLCM or delivery process due to its influence to aid in delivery of a high quality product through a well-defined delivery model (Krauss, 2014).

The AOR team has its own requirements and one of the requirements is to provide mitigation measures for all the project risks. The AOR team provides oversight on the register used for risk management of the gaps in the project, and through this intervention, there is understanding of all AOR threats in a project. The assurance aspect of AOR is an embedded feature in a project, which makes it easy for the team taking over the Asset for O&M.

The following sections cover; AOR requirements, AOR System integration components, and support necessary, which forms part of success factors of a project:

4.3.1. Project AOR requirements

The AOR requirements discussed in this section are in line with details by Horizon Power Corporation (Barnes, 2018).It is clear that there is a need for an organization to invest in all the necessary AOR activities. The following gives the minimum requirements for AOR model as discussed by Horizon Power Corporation (Barnes, 2018):

- The AOR Review intent is to achieve readiness of the plant or equipment prior to startup for purposes of commissioning, optimization, and operation. The Operational Readiness will have a dossier, which consists of several documents for review by the AOR team. In addition, an inspection of the relevant Asset is required.

- The dossier documentation must include but not limited to; procedures, artifacts, roadmap, standards, manuals, pre-commissioning and commissioning, method statement and risk assessment, field manuals, and interphase tracking list.

The trigger for review of the aforementioned dossier, and carrying out relevant inspection, is to validate and verify all data captured in the documentation. Table 1 gives roles for each stakeholder as clarification of the boundaries in a project sphere, vital before carried out activities. The confirmation required to ascertain the state of the Asset is as follows (Barnes, 2018):

- The Asset is required to be safe to energize for purpose of commissioning and operation. The safety boundaries governed by the relevant bodies such as the DoL, ISO, and other local bodies affected by the energization.

RESPONSIBLE PARTY	ACTION
Delivery & Project Manager, Project Director, Main Supplier	Development of AOR dossier as per the handover matrix requirements.
Main Supplier, Project Manager	Management of identified actions that cannot be resolved. Provide support by engaging with the O&M representatives on possible concessions and changes, which are imperative.
Design Team, Main Client	Develop, sight, and review and approve technical documentation such as isometric, drawings, and detailed designs that forms part of the Dossier developed.
Operations Readiness team,	Provide support in the verification and validation process of the dossier to ascertain the completeness thereof. Inspect the equipment based on the developed critical item checklist, and document the results and produce a lesson-learnt document.
Internal Organizational Stakeholder	Conduct a review of all the documentation to provide assurance that the procedure, processes, and specifications are optimal.

Table 1: Responsible parties in the AOR review process (Barnes, 2018).

- The asset quality need to be of international standard to ensure that the end-product is ready physically, and constructed as per the design requirements. This will also require that, pre-commissioning documents and checklist are developed and approve on the right time to ensure smooth commissioning.
- AOR team needs to ensure the operations team has sufficient budget and resources (software, tools personnel, etc.) to assume the duty of operating and maintain the Asset.

The operations team must have the necessary training or competency to perform the “works” during asset operation.

4.3.2. AOR Component System Integration

System engineering as outlined by US Department of Defense (Office of the Deputy Assistant Secretary of Defense for Systems Engineering, 2017) provides insight on ISO/IEC 15288 standard for project delivery. The standard provides an overview of establishment of a framework which could be utilized in a project life cycle. The consideration includes the physical system, system engineering processes, human interface, software, data, and procedure. The need for system engineering arises from its influence in ensuring that a project aligns with the business expected outcome from the initial to final stage of the project.

The expectations from the system engineering perspective will include; the stakeholder relationship, agreement and requirements, concept formulation and evaluation, as well as providing the necessary support for successful asset delivery (Krauss, 2014). The synergy provided by a well-implemented systems engineering is mainly to eliminate the gaps in projects which emanate from the interphase between people, tools, and processes.

4.3.3. Project Support

The project support section covers three main areas of AOR which includes; capacity and competency requirements, handover readiness of a project, and Asset performance requirements.

4.3.3.1. Competency Requirements

Competency in a project is one of the major elements, which should never be isolated from the AOR framework as this has major consequences. The AOR team, operations team, and maintenance team, has difference attributes which are critical to the success of operational readiness (Krauss, 2014).

In the initial stages of the project, the design team often works in isolation from the Operations and Maintenance (O&M) team, and this leads to documents such as, maintenance philosophy not adequately developed to meet the requirements of the take-over team.

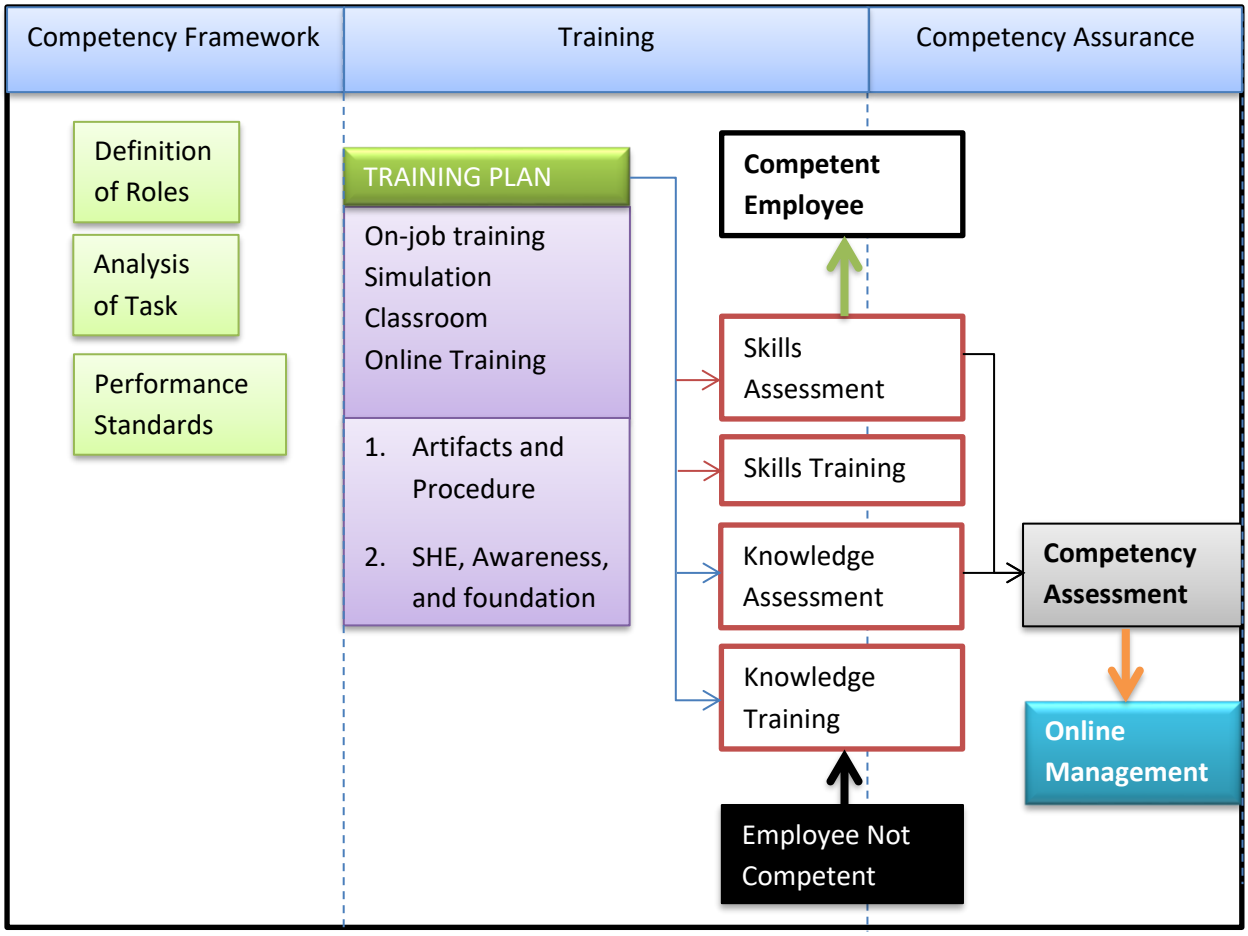

Figure 7: Operation readiness competency model (Krauss, 2014).

Involvement of the O&M team in the early stages of the project has major benefit, particularly to ensure that all the teams are aware of the modifications or changes in design, as well as changes made to operability and maintainability documentations. The O&M team requires training at early phases of the project to understand the O&M requirements, and gain awareness of the technologies and modifications.

4.3.3.2. Project Asset Handover

Asset handover is a transition process from construction to takeover and operation of the Asset, normally carried out between the service provider and the client (Transport Asset Standards Authority, 2018). The process aims at shifting the ownership and responsibility to the Operations and Maintenance (O&M) team, and this is applicable to new asset and modifications. Handover matrix is often a tool used in a handover (HO) stage of a project to outline the acceptance criteria as

means of assuring smooth transition from design and construction, to takeover phase.

4.3.3.3. Managing and Evaluating Engineering Asset Performance

Engineering asset performance has become a significant part of ensuring a Business meets its objectives and goals by evaluating and managing the assets in a continuous basis. This becomes one of the elements fulfilled to ensure that the equipment last for the duration stated on the OEM documentation. The asset performance evaluation aims to prolong the life of the asset, by alleviating negligence, which results in unexpected failures.

The study by (Mo & Saidi, 2014) deals with Engineering system support and structure for performance scoring, and it is important to understand the performance of the asset. The systematic process caters for several aspects of the asset in terms of human, physical, and process perspective, as means of enhancing the conditions. Figure 8 depicts typical performance evaluation methodology, conducted for industrial manufacturing process.

The performance equation in Figure 8 consists of three parameters for evaluation purpose. The X, Y, Z (human, physical, and process) parameters are sum of the weight in terms of ranking. The sum is based on the several sub-elements of each major aspect (i.e. human) of manufacturing. A performance measure will be a tool used to justify any changes or improvements on the process, and such model of evaluating the performance will require continuously improvement to meet the changing environment and technology in the Business.

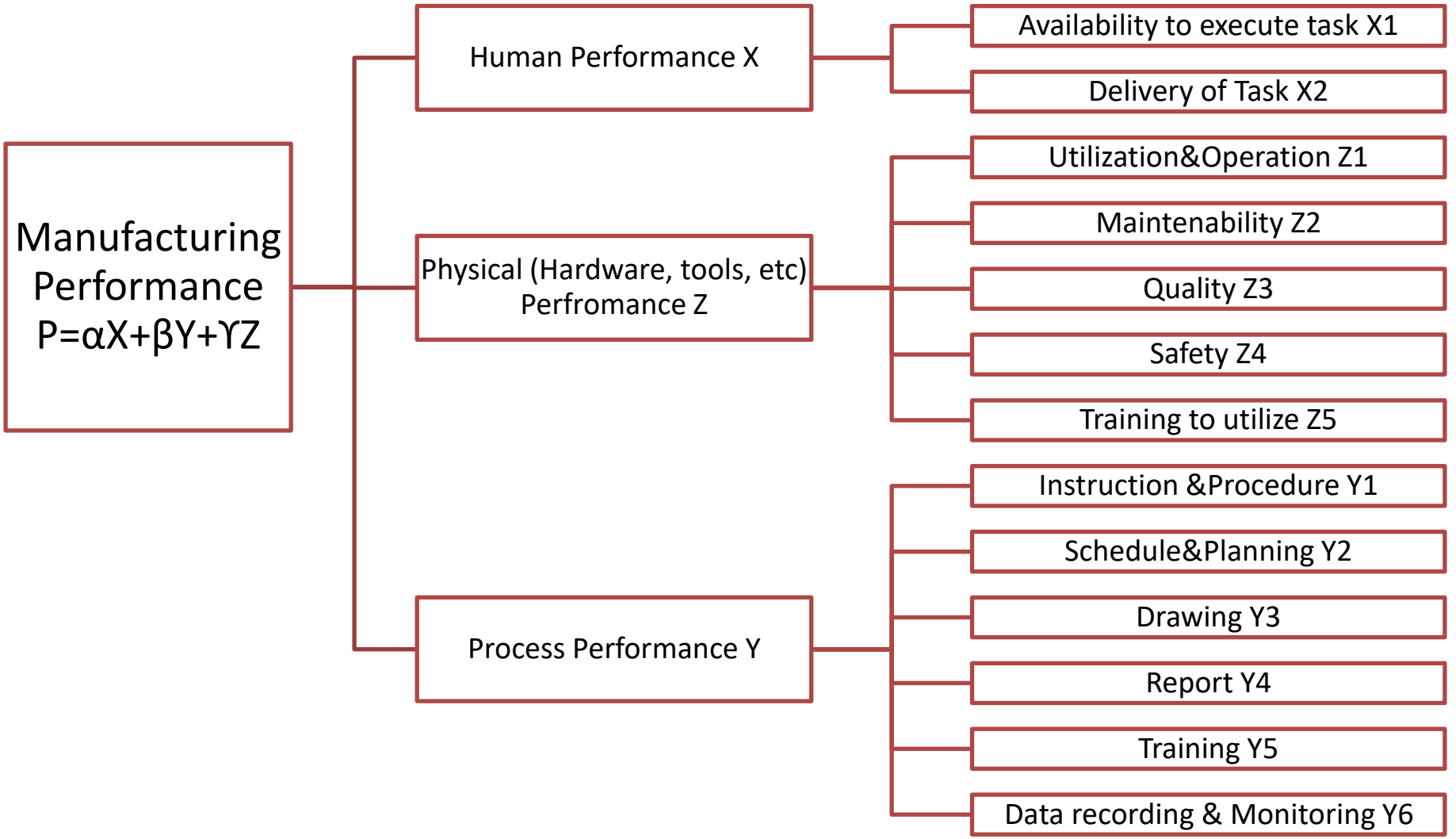

Figure 8: Proposal for Process Industry performance evaluation (Mo & Saidi, 2014).

4.3.4. Project Management AOR Framework

Asset readiness is a process, which needs to be active as the project commences, and implemented within the Business goals and objectives. The inclusion of AOR in a project during initiation, requirement definition, design, and implementation phase is mainly to ensure the organization is ready, and enables adaptation to the proposed changes. In addition, the aforementioned also enables design alignment with the environmental requirements, and ultimately assists with effective O&M requirements (Gardner, 2001).

Figure 9 shows a PLCM from project management perspective as understood by the project management Institute Inc. (Gardner, 2001). The key areas are broken down into; baseline, setup, readiness tools, and plans and artefacts for implementation. The listed key areas are as follows:

- **Baseline:** The baseline sets the tone for assessing the condition of each of the factors, which might influence the successful implementation of the project. The assessment phase will have baseline and re-baselining to ensure capturing of details required as the project progresses.

  The factors which are baselined include; the culture, systems setup and infrastructure, process for operating, functional relationships and interrelationship as highlighted in Figure 12, budgeting and applicable investments, facilities and inventories, IT systems, training availability, as well as project contingencies. These factors play a crucial role in ensuring that AOR is achieved during the development of the project, and once the necessary details have been produced the project plans are then updated to suit the project vision.

- **Project Arrangement:** The project setup needs to take into account the items listed during baselining, as those items align with the project management (including project team) responsibilities to ensure AOR is implemented throughout the PLCM. The reviews, which the project team and management partake in, improve implementation to aid with the broad view of benefits associated with the end-product benefit the client. This means that a continuous assessment is inevitable in a project when aiming to supply a good product.

- **Readiness Elements:** The element that assists during project phase to do a thorough assessment on the readiness to operate includes; prefeasibility assessment tools, execution checklist, risk assessment tools, and communication process.

  The pre-assessment provides an overview on the readiness state of the project, and aid to provide insight on the changes associated. In addition, pre-assessment also aid with; amendment of milestone target, understanding of the RACI structure arrangement, end-product requirements definition, feedback communication plans, and stakeholder relationship.

  The execution checklist provides a stepwise process for all intervention points, which the implementation team should adhere to when performing the activities detailed in a PLCM. The assessment of the associated risks provides a matrix for all the threats concomitant with the project throughout the PLCM.

- **Plans and Artefacts for Implementation:** The plans and artefacts for implementation include the templates to capture all the progress in each stage of a project. This covers the approach, which defines the direction necessary to deliver the end-product. The Plan should include the breakdown provided in Table 2 and Figure 3.

The areas detailed above and Figure 9 provides a good basis for AOR, and alludes to which of the areas each element of AOR requires per PLCM phase. This rather requires synergy during implementation of each element of AOR process.

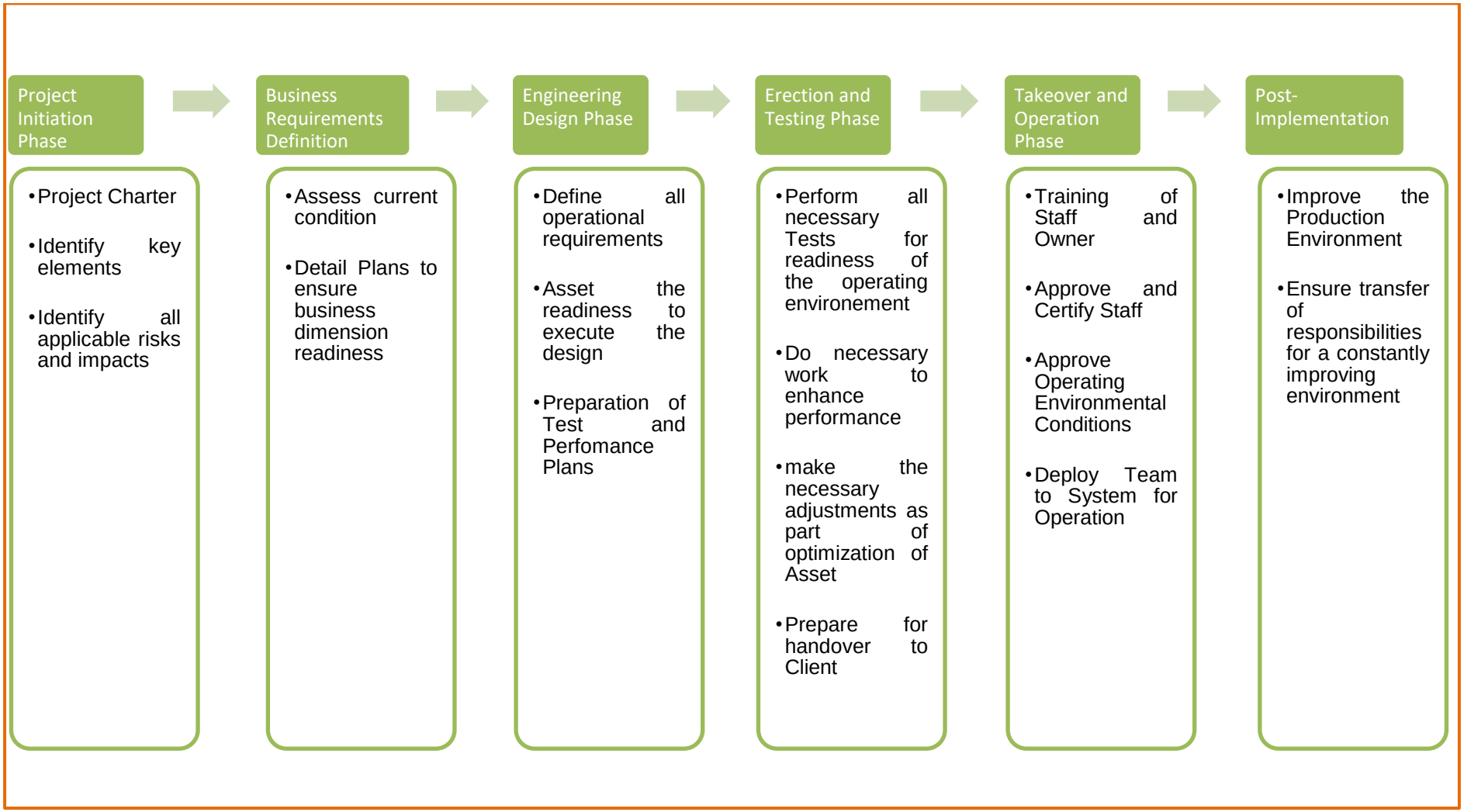

Figure 9: Project management operational readiness key elements, reproduced (Gardner, 2001).

4.4. AOR Standards Overview

The AOR Standard overview section aims at providing insight on AOR perspective, particularly for bodies of standards. The section covers overview of AOR from EPRI as well as US DoE as a minimum amongst other standards which were not considered as part of the literature review.

4.4.1. AOR Inter-operability Framework

There is a drive to convert the grid systems to a smart grid, and institutions such as EPRI have invested a vast amount of time in research to aid with implementation aimed at achieving an adaptive and stable grid system.

The requirement to achieve a stable grid system remains a driver by several Organizations, and there are initiations to fund projects aimed at collecting data that can be utilized for improvements thereof. The data collected provides a good basis for planning, operation, and maintenance of power equipment to meet the requirements of a smart grid.

The National Institute of Standards and Technology (NIST) was mandated to coordinate development of a framework which covers protocols and model standards, that enables management of information in order to successfully meet an interoperability of smart grid system (National Institute of Standards and Technology, 2014). NIST has detailed a framework for smart grid interoperability standards, which gives an overview of all necessary attributes for implementation thereof.

Table 2 gives an overview of the key areas, considered as drivers in an organization to strengthen the multidisciplinary integration. In an Organizational structure the technical, information technology, and organizational makeup, will be essential for the success of the AOR as these areas provide synergy to best address the complex developmental environment.

Figure 10 provides elements embedded in the Inter-operability composition, which include configuration, operation and improvement, and the risk factors.

MAIN DRIVER	SUB AREAS	DESCRIPTION
Technical	Basic Connectivity	Relates to Inter-connection and synergy of equipment particularly, system for optimized outcome.
	Network Interoperation	Communication between different systems using signals, operation room monitoring, and so forth.
	Syntactic Interoperation	Knowledge to interpret the signal and specific reports from the communication issued.
Information	Semantic Understanding	Knowledge of the concepts developed as part of drive to achieve operational readiness
	Business Context	Clear understanding of the business goals for interrelationship of information and systems
Organization	Business Procedures	Integration between business mandate of operation and the applicable process and procedures
	Business Objectives	Strategic and tactical objectives detailed in the Organizational strategic plan.
	Economic and Regulatory Policies	Political motivated and economic objectives as prescribed by the regulatory bodies and the government.

Table 2: Inter-operability composition overview (National Institute of Standards and Technology, 2014).

The NIST institutes' architecture on Smart Grid has five key conceptual areas, which include:

- Specifying the dimensions and objectives to meet the requirement of the national grid system while taking into account the policies associated,

- Develop a well-defined and formalized list of requirements, detailing all the business services to meet customer needs and demands,
- Automate services where necessary, and integrate the communication system and the business services for optimum performance (National Institute of Standards and Technology, 2014).
- The concept phase forms part of the envisaged process, which covers concept logic that integrates generation with distribution, physical execution, and implementation.

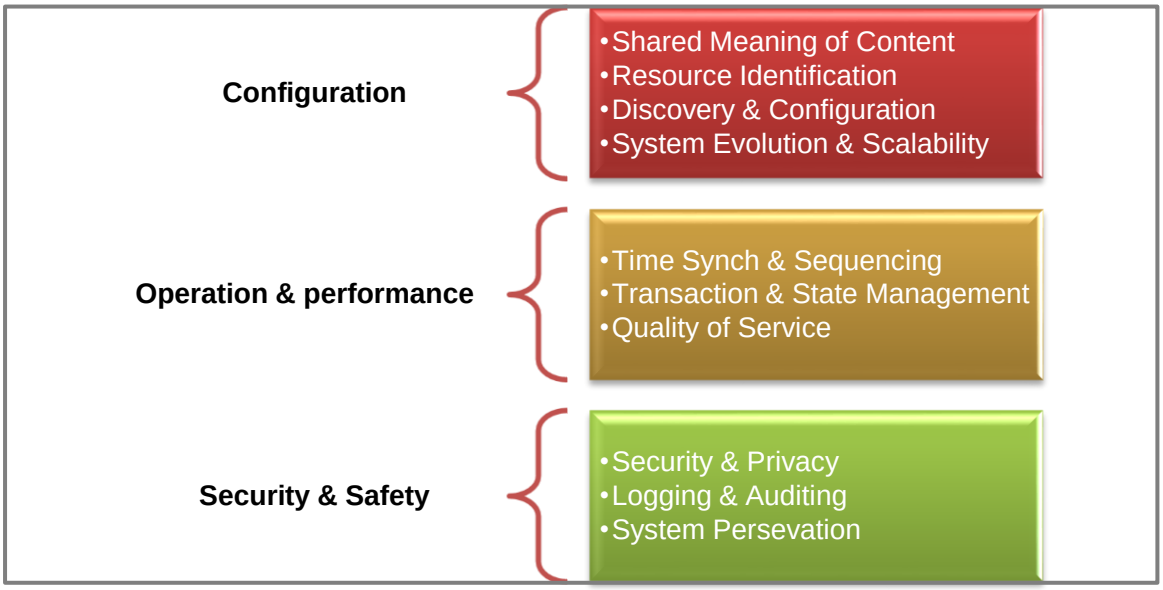

Figure 10: Elements of the Interoperability structure for optimization of AOR (National Institute of Standards and Technology, 2014).

Table 2 and Figure 10 provide a good basis for structuring the AOR plan for a system so that there is a successful and a comprehensive final product with the required competence and skills.

Organizations such as EPRI have identified three main readiness elements (Knoxville, et al., 2015) which are necessary for the success of readiness assessment, and that includes:

- The statistic levels: This provides insight for achieving required resource capacity, and process application.

- The process level: This provides a stepwise approach, Organizational structure, and engineering and automation of the interconnection process.
- The functional level: This provides insight into the interconnection status.

The aforementioned items need to take into consideration when designing a successful AOR for an Organization. The indicators assist to ascertain achievement of AOR process targets in each project gate of the implementation stage.

4.4.2. Department of Energy AOR Framework

The United State Department of Energy (US DoE) defines AOR as a configuration which aims at optimizing all necessary resources (personnel, software, hardware) during the initial stages of a project, while taking cognizance of the applicable procedures and management controls (Nertney, 1987). This implies that for adequate and effective Operations and Maintenance (O&M) the assets should be in a state, which does not compromise the integrity and functionality thereof.

Figure 11 shows that the process which needs to be followed in the life cycle (LC) of the asset. The development towards AOR is on a clear knowledge of the procedures and processes involved with the systems.

Safety clearance of the system for operation requires that the technical specifications, operating limits, management controls, and quality assurance requirements, detailed to an extent to which there is a clear alignment and interoperability between different systems and departments.

AOR achievement entails that the elements highlighted on the Figure 12 have provision in the AOR phases as indicated in Figure 2. Figure 12 shows that there are six elements which needs to be taken into consideration, and include Organization's procedure, equipment and hardware, personnel, as well as the link between the procedure and hardware, procedure and personnel, and also personnel and hardware. The aforementioned elements require process in place, which will ensure successful implementation of AOR in project.

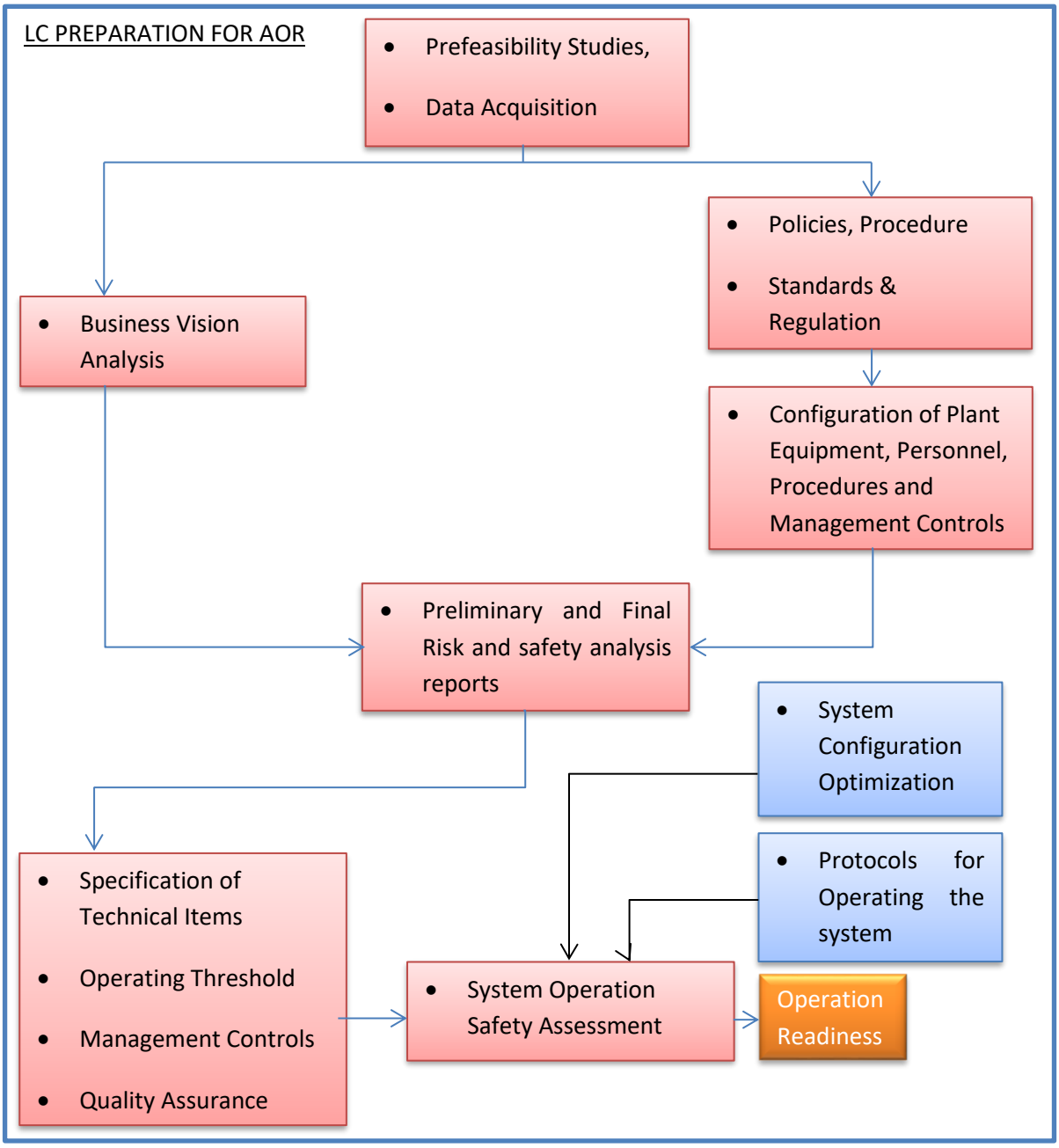

Figure 11: Development Cycle through PLCM, reproduced (Nertney, 1987).

In Plant systems, which are complex, there is a need to have the correct analytic models that will aid to track all the elements listed above. The analytic model should have a structure, which associates the various elements as well as ensuring that the management, supervisory, and operating structure enable a seamless alignment with the plant structure (Nertney, 1987).

4.4.2.1. Physical Equipment Challenges

The gaps and catastrophic failures (i.e. floods) in a newly commissioned system are good indicators of systems, which are not operationally ready for the intended purpose. This narrows down to the process steps detailed in the elements highlighted in Figure 3.

The cases whereby the team has no control over such as weather related occurrences, provision should be included in the design. An illustration can be a lightning strike threats alleviated with a proper grounding techniques, as well as other catastrophic events, which requires a detailed recovery plan in place as a mitigating factor.

4.4.2.2. AOR Process Monitoring

In any Organization, it is essential to implement tracking mechanism, which will show progressive status over the AOR phases. The systematic tracking method provides an indication of how the operationally ready the plant or system is for client takeover.

It should be understood that the final inspection or safety clearance of a system is merely to finalize allow for start-up, which does not indicate rework emanating from the optimization phase. AOR requires consideration of all necessary measures such as visuals, inspection, testing, and acquire all the necessary documentation or records for the work performed.

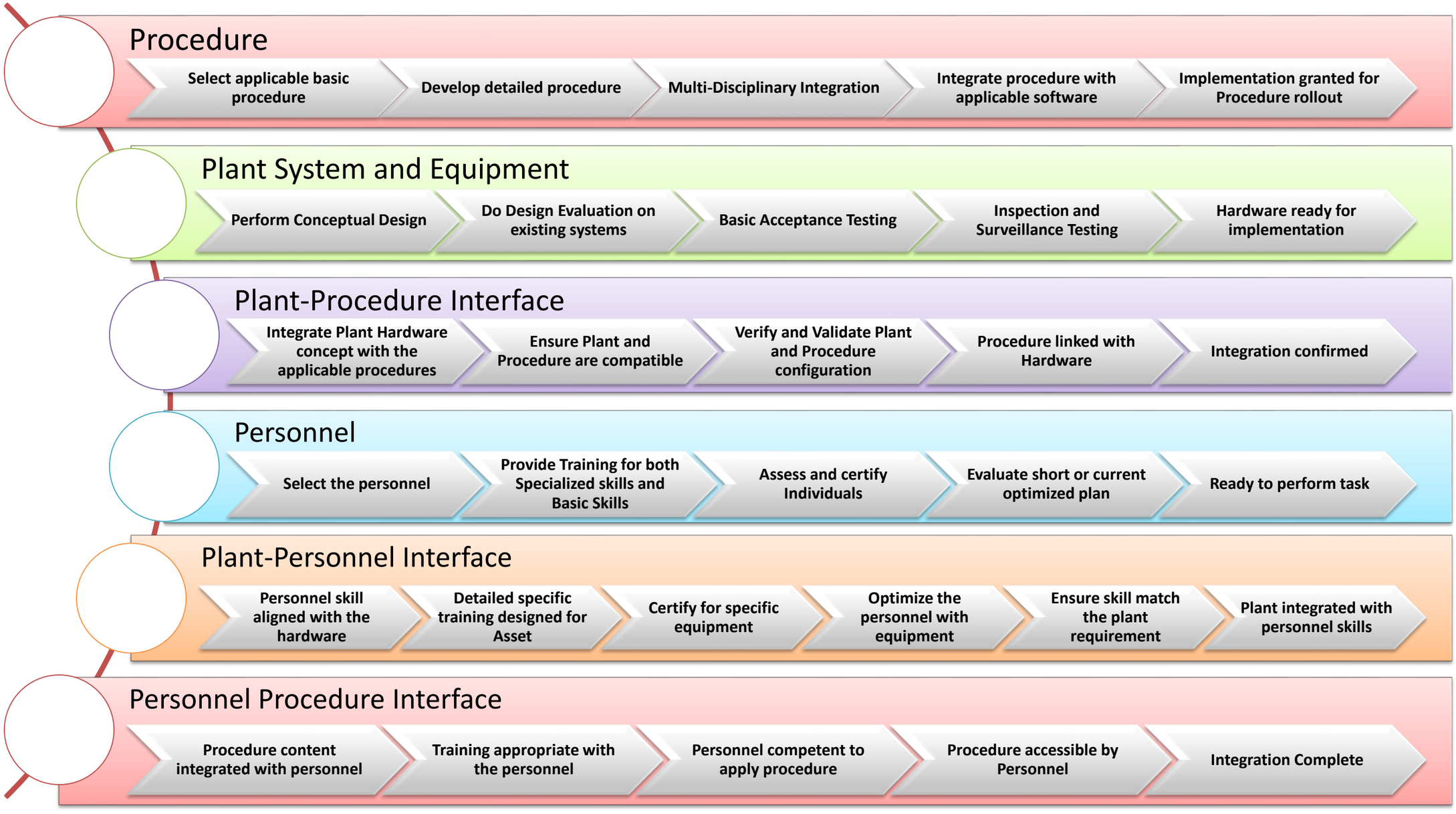

Figure 12: Operation Readiness interrelated project elements, reproduced (Nertney, 1987).

4.4.2.3. AOR Component Assessment and Support

There are five areas in this section detailed by US Department of Energy (DOE, 2010). The areas will not necessary be applied similar to different systems or plants due to the level of complexity of each system, and this requires understanding of the technology to circumvent implementation of unnecessary procedures and processes. The areas as detailed by US Department of Energy (DOE, 2010) are as follows:

- System or Plant start-up needs consideration means that process and procedure should be in place to aid the managing team when assessing if the minimum requirements are met to start-up the system. This consideration needs to cover the design documentation, Operations and Maintenance (O&M) philosophy, and personnel proficiency to takeover. The changes and modification documentation is required through the correct systems, and includes any defects or concession communicated to the client.

- There are cases whereby the readiness review is not considered, and such entails that there is a guide from the Owner Equipment Manufacturer (OEM), which details the processes, procedures, and Operations and Maintenance (O&M) philosophy. The guidance requires a high level of understanding of the system implemented to ensure that there is no compromise on the quality. This event is mostly associated with the systems whereby the manufacturer assumes full accountability, with provision of insurance and warrantees.

- Hazards form part of the factors, which require oversight, and the management includes identification of the hazards and the risk level for every system or equipment. The hazards identified will require classification in order to determine the likelihood of their occurrences as well as the impact thereof. A complex system might not only require skilled personnel but has a potential of increasing the risk associated with commissioning, operating, and maintaining of the Asset.

AOR requires plan of action, which elaborates, on the steps needed for successful implementation of a sound Operation Readiness elements. In addition, it is essential that coining of AOR strategy is specific to a sector or industry to ensure that there is adequate alignment.

4.5. Rail Industry AOR Framework

The product service guide developed by the network rail organization (Network Rail, 2017) covers a variety of Readiness Levels, which includes multiple Asset areas. Figure 14 and Figure 15 show the asset readiness framework. This section of the paper as a minimum covers technology, manufacturing, integration, system, software, and reliability readiness level, which appear in the figure aforementioned. This model is for railway industry but the principle behind the readiness assessment implementation applies in various sectors or organization with Assets.

4.5.1. Physical Asset Readiness assessment

Technology Readiness Level (TRL) scaling is a development of NASA which has received plenty of attention from the various entities due to its applicability in order to meet organizational goals and objectives (Olechowski, et al., 2015). The TRL Scale is a tool used to assess the readiness of the technology in question from the pre-conceptual phase to the production or deployment phase of the project.

The TRL developed includes nine TRL stages which deal with the basic considerations, technology overview, proof of the concept, validation of the concept, prototype development and testing, and product or technology readiness to operate. The stages are designed to measure if the technology is matured enough to perform desired duty, and this has assessment milestones (Bakke, 2017).

The article by Animah and Shafiee products (Animah & Shafiee, 2018) shows a proposed way of evaluating the maturity of the technology as well as commercial readiness for end-of-life. Although the strategy is meant for end-of-life, it is important to understand that the strategy could be used for evaluating technology for capital projects. In the TRL concept, there are other considerations which need to be taken into consideration due to the significance they provide towards the objectives set, such as the commercial process or funding related to the technology and evaluation thereof. The commercial aspect of the TRL is considered through a well-developed Commercial Readiness Level (CRL) which outlines the means of evaluating the readiness to fund or finance the entire “works”.

4.5.2. System Integration Readiness Assessment

The study by Ross (Ross, 2016) details the scientific side of Integration Readiness Level (IRL) and shows readiness levels interconnectivity in order to achieve the best possible solution. The study further details the various areas outlined below:

- **Identification and Characterization:** In this stage, there is knowledge for the interface for the technology required and there is enough data to do a thorough planning as means of ensuring integration readiness. The details for the integration process need to be in schematics and conceptualized so that there is a clear guide for implementation.

  The human factor in this stage will entail identification of necessary resources and confirmation of right skill availability. The characterization will require that the input and output for the integration are well understood and identified.

- **Compatibility:** The order and interaction between the sub-technologies in terms of coding language, assembly is well understood. The qualitative detailing of the interface ensures elimination of the impact of system modelling.

- **Quality Assurance:** The quality assurance ensures that the technology is delivered without any compromises, and the product is of the state of the art and high quality international best practice.

- **Controls and Information:** The controls in place are necessary to mitigate the risk associated with the technology and the interfaces thereof. The control should ensure that the interfacing or interrelationship between all applicable elements of the technology and asset readiness.

- **Verification and Validation:** The verification and validation of the technology requires that the correct and effective model or Framework be in place to ensure assessment of the end-product to meet the requirement without overlooking any significant item associated. This also ensures that the product adopted has gone through the necessary process that aims to optimize the performance of the technology for high productivity during operation.

- **Finalization:** The finalization stage is to ensure that the technology is ready for the purpose intended for without any compromise on the integration, safety and environmental aspect, technical integrity, functionality, as well as operational and maintenance effectiveness.

4.5.3. Manufacturing Readiness Assessment

There are several elements of manufacturing readiness level, which require careful consideration during maturity of a technology or product to ensure optimum quality assurance. The elements outlined below are in line with international best practice as detailed by NREL (Wheeler & Ulsh, 2010) and US Department of Defence (OSD Manufacturing Technology Program, 2011), and the elements are as follows:

- The basic manufacturing preparatory and conceptualization is one of the key initiation stage of Manufacturing Readiness Level as this phase aims at identifying the risks associated with the execution of the project Assets prior to erection or construction. The application identification and concept verification forms part of manufacturing readiness requirements to ensure quality final product delivery. There are various organizations, which have seen major gaps in this stage of their projects, and this had high contribution to the misfortune of the final product while having severe impacts on the maintenance stage of the project.

- There is always a need to produce a prototype for any technology which will be utilized by a business, this is mainly to ensure that the necessary Factory Acceptance Tests (FAT) are performed, which deem the product fit for purpose. This stage of capacity verification also includes the assessment of the material, the welding process requirement, and other testing methodologies such as Non-Destructive Testing (NDT) as well as destructive testing. This stage will cover the capabilities in the laboratory, the prototype (components, subsystem, and systems) manufacturing capabilities, and simulate the prototype to ascertain the environmental impact during storage, construction, and operation.

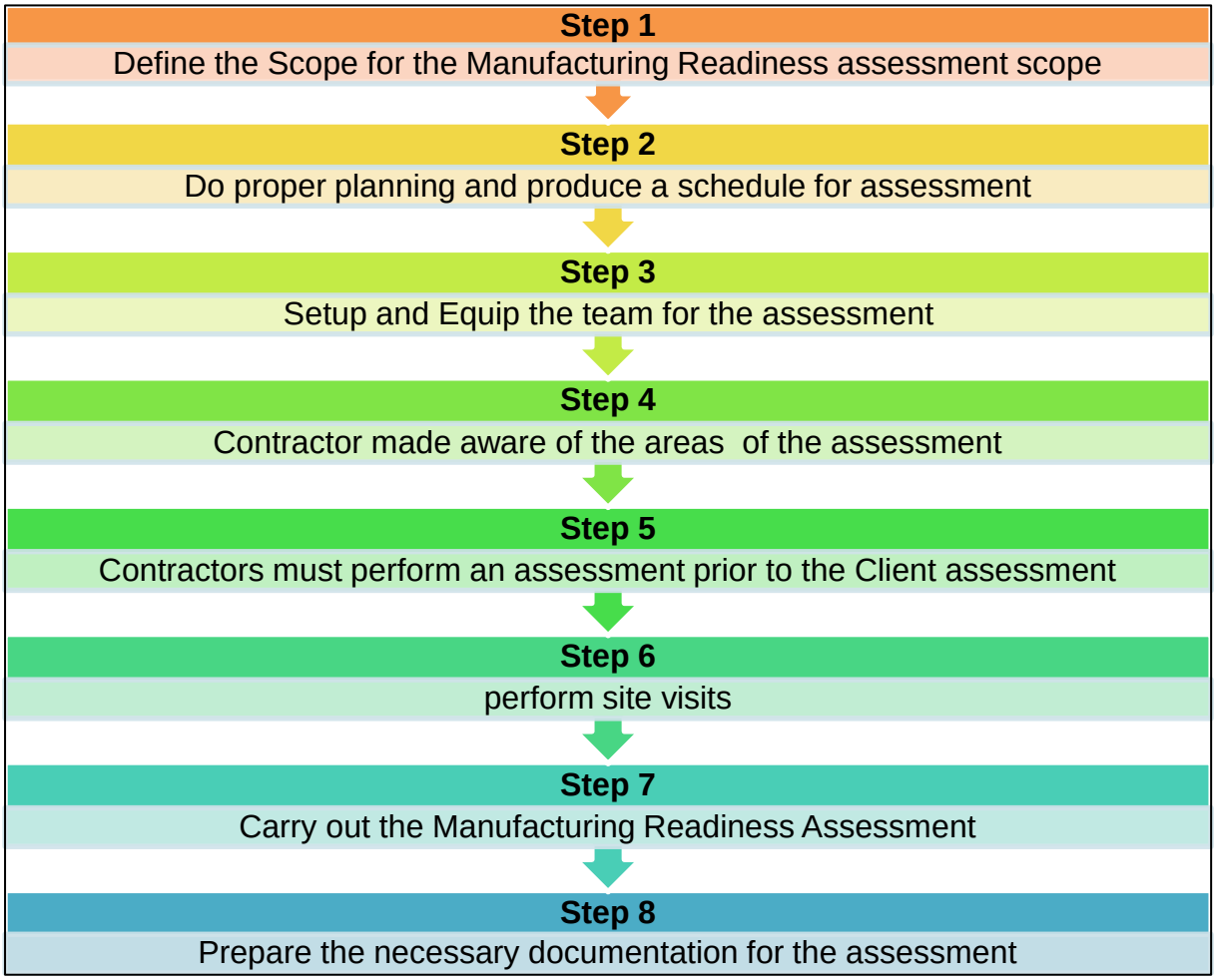

Figure 13: High-level process flow showing a stepwise assessment of manufacturing readiness, reproduced (Okes, 2009).

- The previous stages are providing assurance that the product can be produced for commercial use and it is expected that all errors identified during prototype development and testing are resolved prior to any commercial production whether low production rate or high production rate. The key in this stage is that there is no doubt in terms of the performance, RAM, quality, Engineering integrity, and logistics to relevant site or location.

There are several means of assessing Manufacturing Readiness Level (MRL) and the flow process depicted on Figure 13, gives a high-level sequence to achieve readiness during manufacturing.

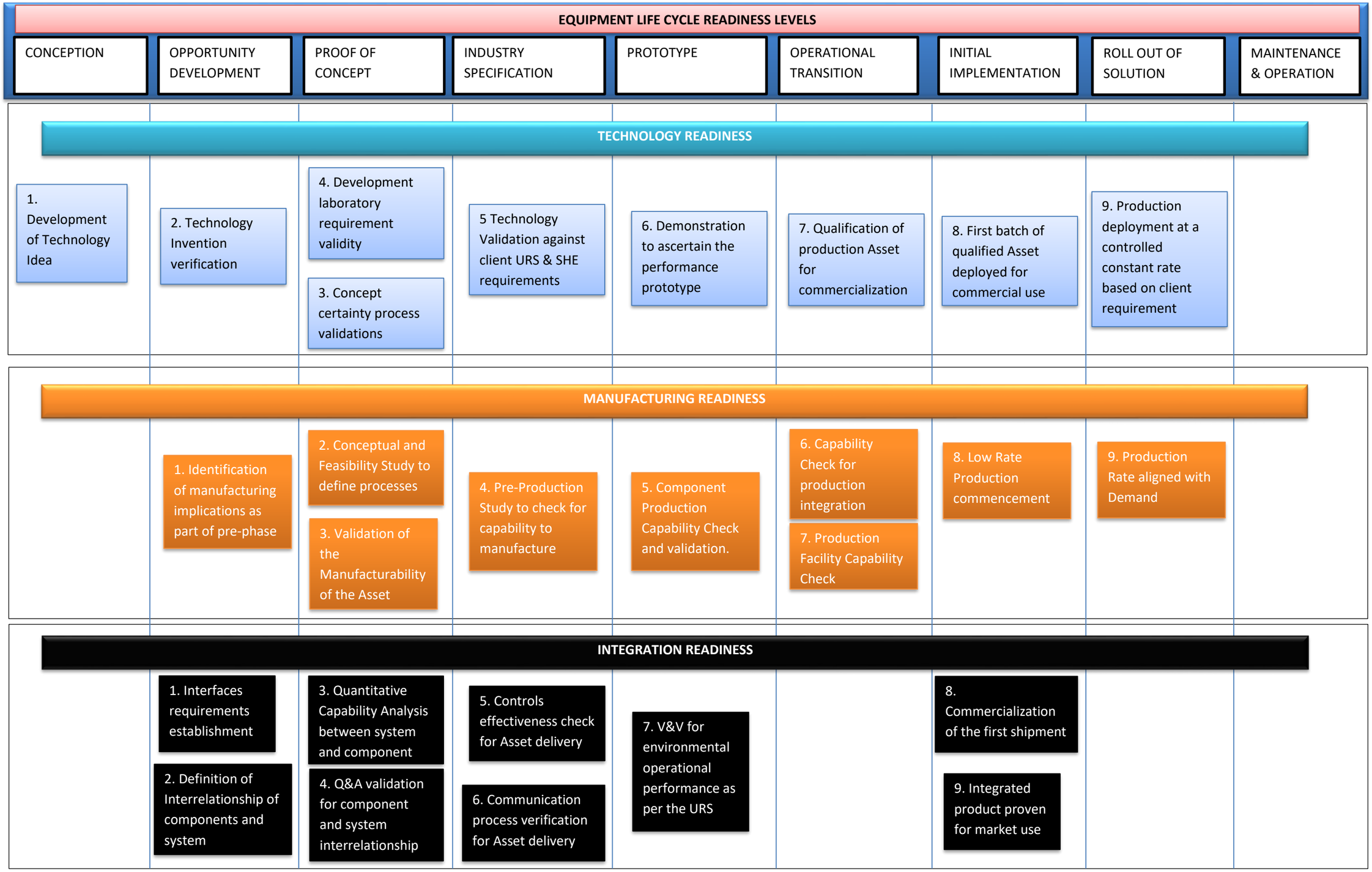

Figure 14: Railway acceptance criteria which cover IRL, TRL, and MRL, reproduced (Network Rail, 2017)

4.5.4. System Readiness assessment

System readiness assessment is one of the necessities for a sound product delivery as this assessment provides system assurance to aid in mitigating any associated risk. System Readiness Level (SRL) assessment main role is to ascertain if the system is at a right state and maturity for purpose intended. This does not only deal with the maturity but it also helps to verify the performance of the system for the intended purpose and provides assurance on the integration of each component to achieve an optimized design (Austin & York, 2015). In addition, a system is satisfactory if it has met the stakeholder requirements, well integrated to obtain flawless operation and functionality, meeting the required performance at the specified capacity, and meeting the environmental requirements (Mabelo & Sunjka, 2017).

System Readiness Level index consists of five elements but the breakdown differs slightly depending on the approach used and the intention. SRL covers as a minimum the following (Sauser, et al., 2006):

- Product conceptualization caters for system strategy development,
- structured technology integration while ensuring reduced technology risks,
- system development and pilot demonstration,
- Technology or system production and ensuring that the criteria are met for operational requirement,
- Operational and support whereby the operational needs are catered for in terms of maintainability, sustainability, reliability, and cost-effectiveness of the life of the asset.

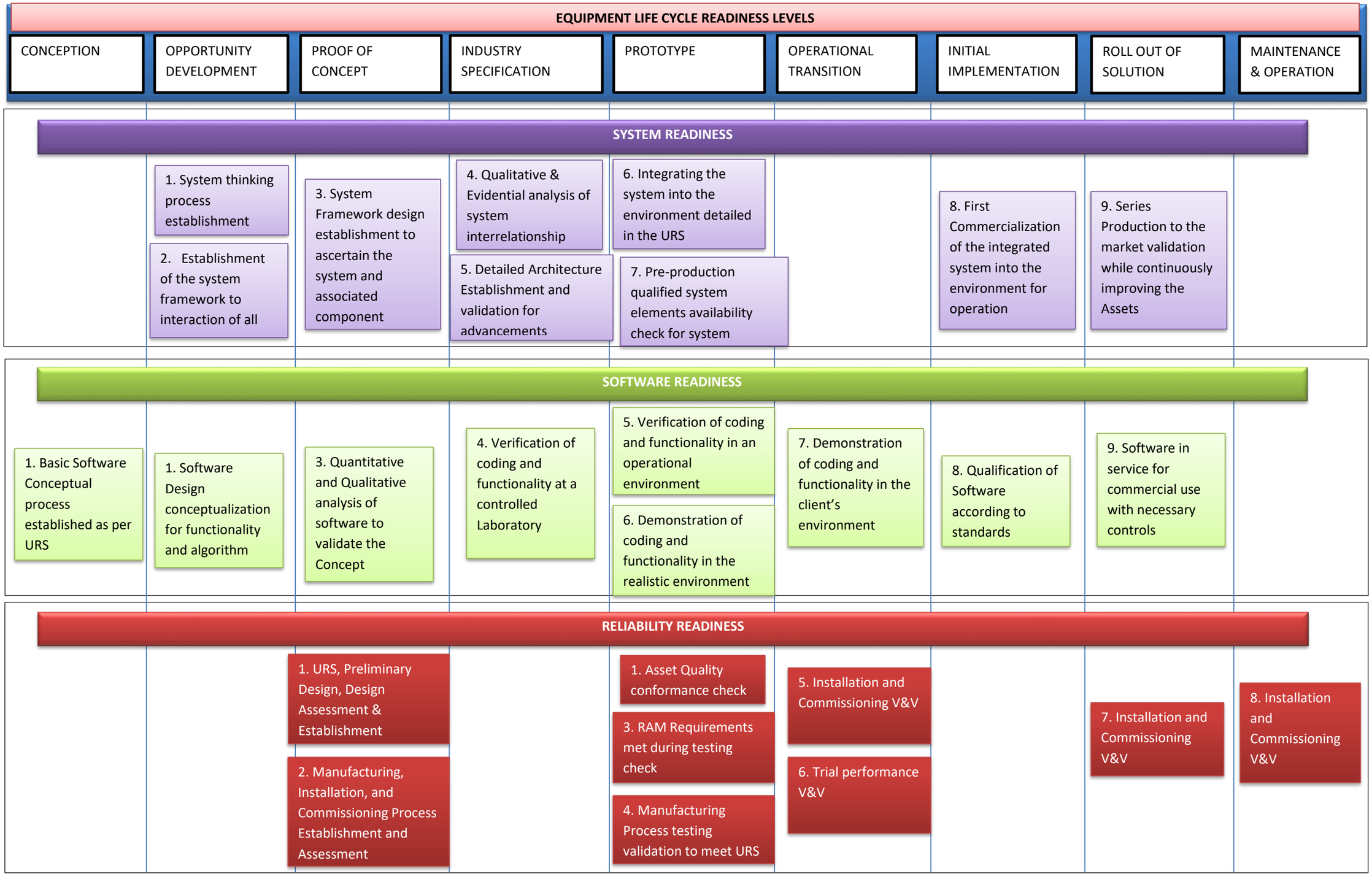

Figure 15: Railway Acceptance criteria which cover SRL, SwRL, and RRL, reproduced (Network Rail, 2017).

4.6. Mining and Oil Industry Project Readiness

AOR has become essential for all types of industries due to the challenges various industries face during the O&M stage. Project such as oil, gas, as well as chemical have noticed an increase in terms of its sophistication and project or plant scale which calls for a good AOR program which can ensure that in operation there are no issues or any catastrophic which will result in high maintenance costs.

The major contributory factor to high cost is the challenges that arise when commercializing the Asset and this has resulted in cost and schedule overrun in many project (Bond, 2017). Some of the challenges arise during resource optimization, logistics, and equipment acquisition. Understanding of the aforementioned challenges will assist to reduce any risk during operation through a systematic process, which can verify the health of the plant and integrate with the right skill-set (Asia Industrial Gases Association, 2017).

4.6.1. Readiness Related Challenges

Projects have reality according to (Asia Industrial Gases Association, 2017), which requires well-structured AOR approach as a mitigation measure and there are as follows:

- Increase in project complexity and sophistication require processes and governance from the business.
- Regulatory requirements that are constantly changing, and resulting in an increased risk of compelling the business to phasing out of certain systems.
- Geographic setup resulting in challenges relating to skills and competency capacity, logistic and supply chain, and political and socio-economic instabilities.
- Staff and resource levelling related changes.
- Customer demands leading to projects pressured to deliver a product even in cases where it is not realistic to do so.

4.6.2. AOR Remedies for Challenges

An AOR framework, which can enhance performance of a business during operation, will require a practice that can remedy most of the challenges, or all challenges aforementioned to a certain extent are as follows (Bond, 2017):

- Do the planning at the right time during the LC, which entails planning in the concept and design phase with the aid of all relevant stakeholders. This will reduce unforeseen circumstances at the operating stage.
- Develop O&M strategies and procedures during the early stages of the project as means of proactive action. In addition, this should include the non-conformance consideration.
- Ensure that there are procedures which cover every element of the project to provide confidence on that there is as-build documentation at the end of the project
- Ensure that there is capacity with the relevant competence and skills to commission and operate the plant.
- Ensure that there is training program and a department which aims at development of skills within the Organization. The operator must be ready to operate the Asset once commissioned.

4.6.3. Mining and Oil Industry AOR Framework

In the field of oil and mining process safety operational readiness is an essential element as it forms part of the “risk based process safety” (Hendershot, 2014) and is also an element which is associated with the safety standards intended for best practice standardization of safety aspect of pre-commissioning in new and modified plants. The needs for a more stringent approach for chemical industries arise from the complexity and high hazardous nature of the field. The AOR required is not merely a formalization of the structure but it is intended to deal with the gaps in the processes by intervention which can assist with a detailed verification and correction of the procedure and governance.

4.6.3.1. Flour Corporate AOR Framework

Flour Corporate has detailed the elements which exist during the life cycle of a facility or plant, and the elements include maintenance readiness, operations readiness, systems or equipment readiness, LC Activity support readiness, Organizational readiness, logistic and supply chain readiness (Flour Corporation, 2011). The Section below will detail the aforementioned readiness element as shown in Figure 16.

a. Operational Readiness Establishment: Operational readiness planning is an involved part of the entire AOR framework, and it includes Organizational tasks, responsibility and roles associated training and competency establishment, the O&M strategies, certification & accreditation, and material management.

The other areas include; plant start-up, production ramp-up, risk assessment, and identification of any opportunity, which enhance the performance of the project.

b. Capacity and Resource Levelling Planning: The capacity establishment consideration is at the early stages of the project life cycle as shown on Figure 16. This area covers the analysis of the local capacity, community analysis as a due diligence study, site development and selection, and permitting through environmental assessment studies.

c. **Maintainability Readiness Establishment:** The establishment of maintenance readiness involves the following:

- Reliability, Availability, and Maintainability (RAM) Model Implementation.
- Monitor all activities to enhance the maintenance strategy performance.
- Optimize spare parts management and acquisition.
- Align maintenance department with the commissioning activities and agreements.

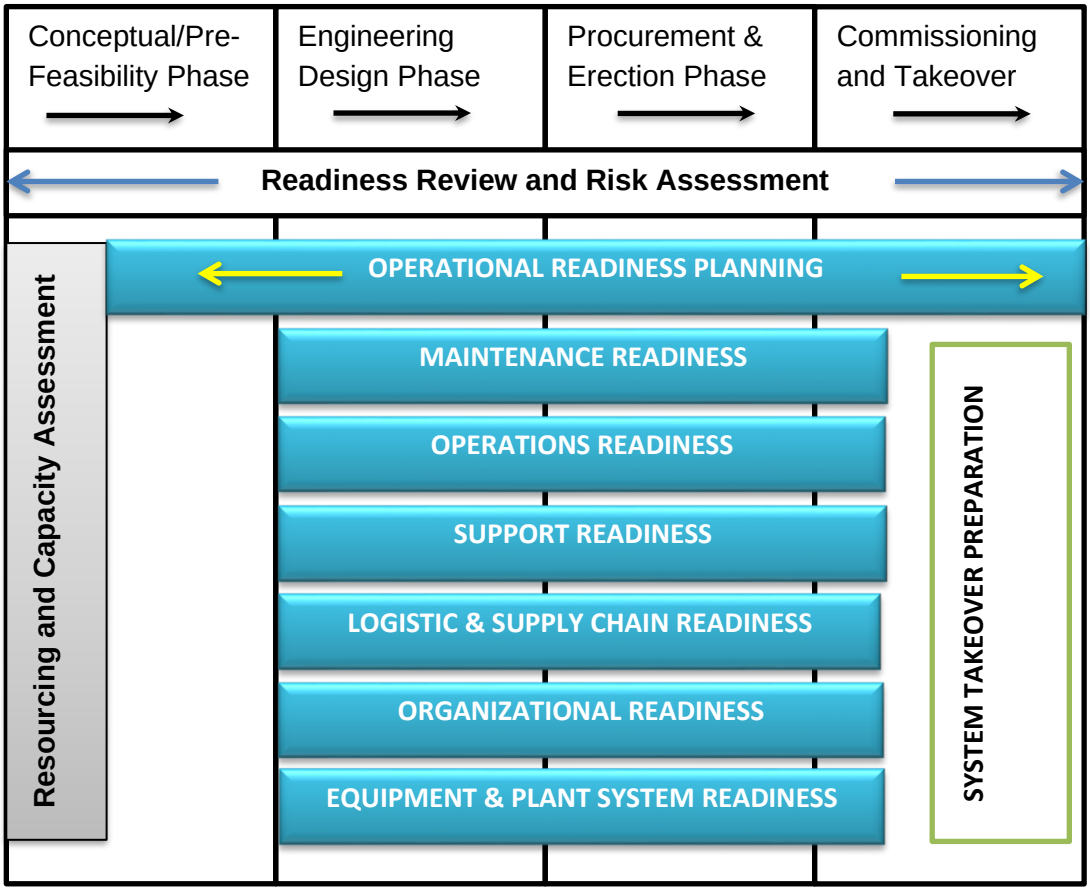

Figure 16: AOR with integrated sub-areas applicable for various projects, reproduced (Flour Corporation, 2011).

d. **Equipment and System Readiness Establishment:** The system or plant readiness incorporates system strategy from the design phase to the construction and commissioning phase while ensuring that there is; overall information, database created, tools and facilities established, and the right personnel manages the systems. In addition, this also involves integration of the IT model with the system for adequate communication. This areas needs to take cognisance of the contract used for project execution and integration all systems plans.

e. **Supply Chain and Logistic Readiness Establishment:** The supply chain establishment should include the envisaged business strategy, and processes and procedures intended for procurement. The procurement covers project components, material acquisition and preservation, and post commissioning database for maintenance equipment acquisition.

f. **Life Cycle Support Readiness Establishment:** The support system establishment includes the SHEQ department, Plant Engineering, and the necessary services for the built facilities, the utilities department, and integration of all the governance with the support system.

   The detailed AOR stepwise process shown in Figure 17 to Figure 19 covers requirements throughout the PLCM. The requirements aforementioned in the literature review in-depth provide a stepwise process, with interlinked process in each phase for clear understanding of where each component plays a role.

g. **Management of Changes in a project:** Changes management is one of the key elements of a project, which an organization needs to factor in their operational model. The study by (Levovnik & Gerbec, 2018) details change management in pursuit of a model, which can assist to manage all the changes in a business. The change in this study includes modification, retrofitting, addition on the original design, removals, or changes to the governance, process, and procedures.

   There are various ways to manage the changes, but it is important that there are systems or models in place to ensure effective and efficient implementation. The study shown also promotes interface optimization, in line with human-procedural, physical-human, and physical-procedural interface. The aforementioned combinations by Nertney (Nertney, 1987) ensure project success by ascertaining that the organization is ready for Operations and Maintenance (O&M).

   The basic process to be followed in change management process includes by maintaining a well-established dependence practice, ability to identify the possible and potential changes, assess the potential risks and impacts, make the necessary decision relating to the changes, and lastly, to finalize all follow-up activities detailed by Gerbec (Gerbec, 2017).

4.6.3.2. Mining Industry AOR Process Flow Framework

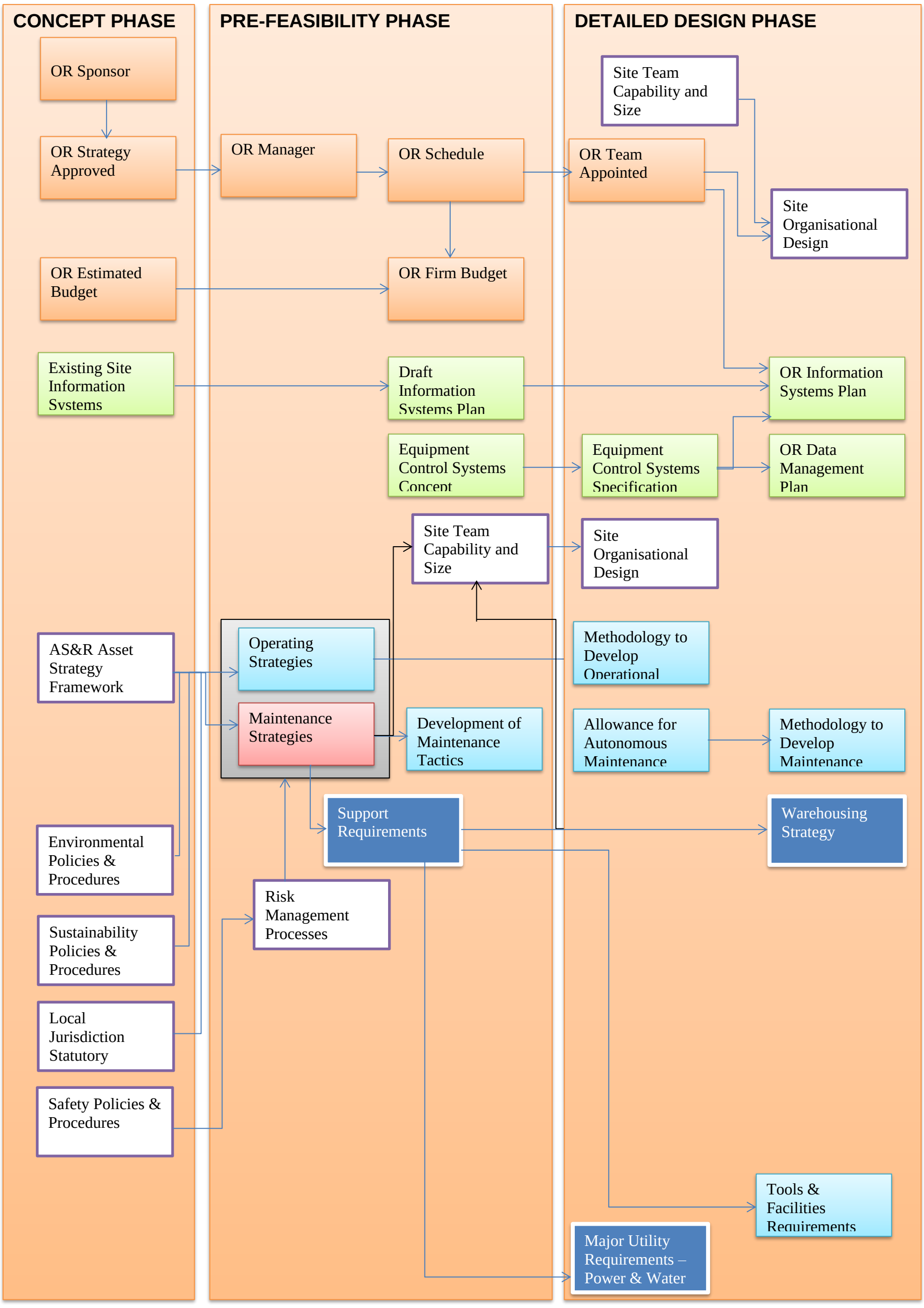

Figure 17: AOR detailed stepwise process flow for design and concept phase, reproduced (Wannenburg, 2016).

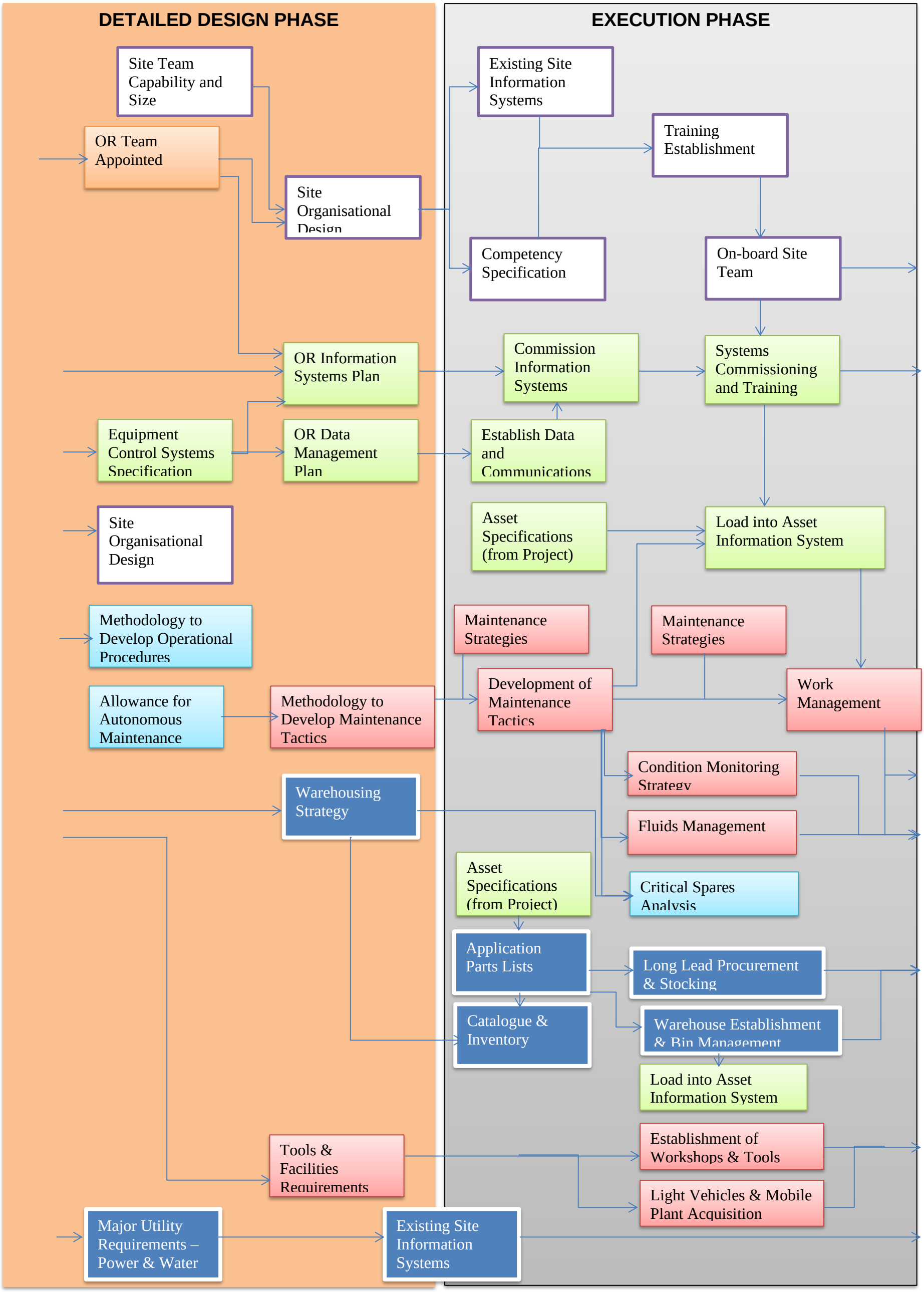

Figure 18: AOR detailed stepwise process flow for design and implementation phase, reproduced (Wannenburg, 2016).

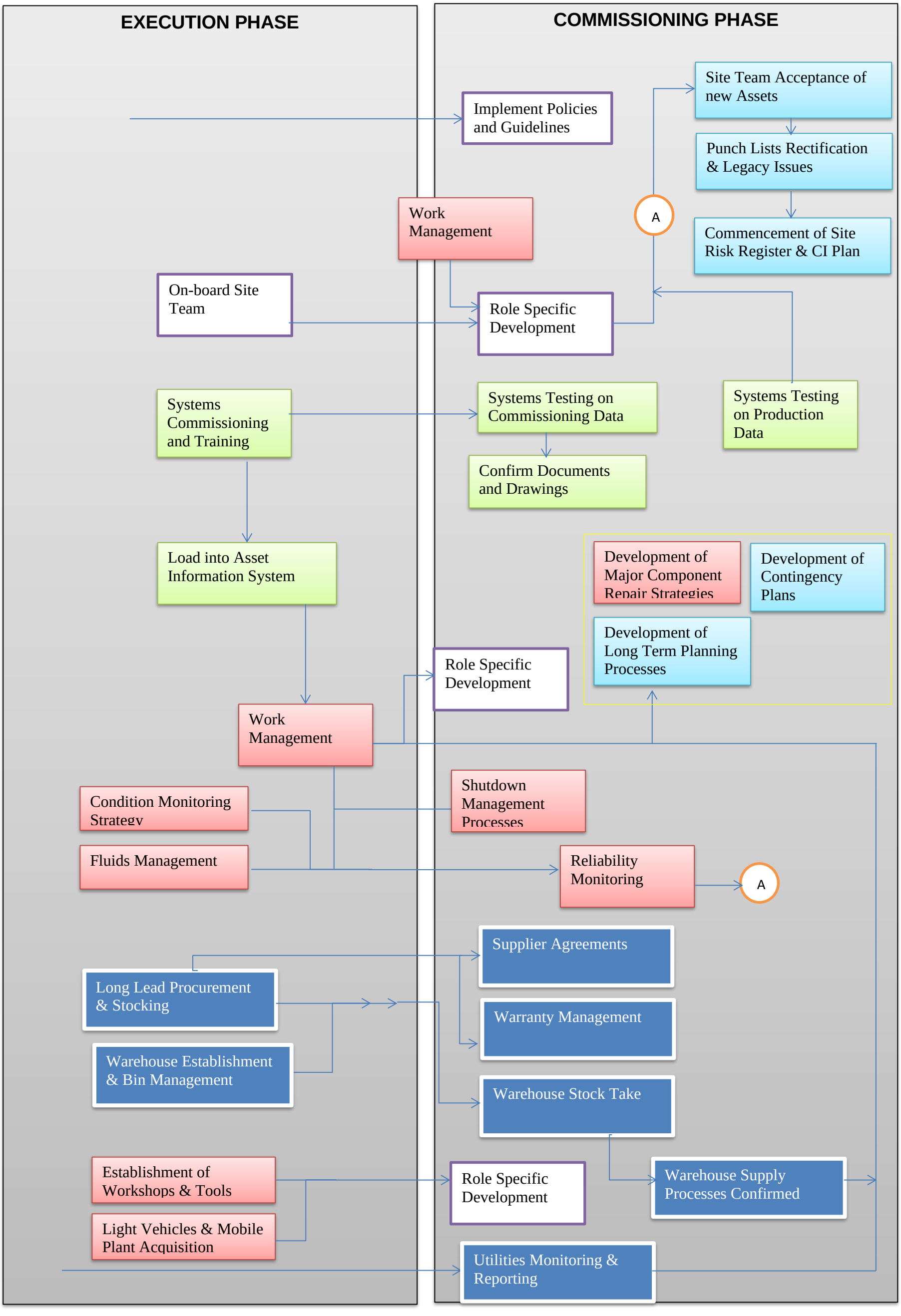

Figure 19: AOR detailed stepwise process flow for implementation and commissioning phase, reproduced (Wannenburg, 2016).

4.7. Asset Maintainability Readiness

Maintenance readiness has become crucial in a life of an asset as it caters for the requirement for successful O&M. The model that yields more benefits for an asset requires a clear link between maintenance, quality, and production, which aligns with the objective of an organization to fulfill its goals (Zuo, et al., 2016). The end-product needs to possess all the characteristics acquired by following all elements mentioned below.

4.7.1. Maintenance Strategy Readiness

Production is one of the major elements of profit impact maintenance due to its influence on the financial position of an organization. The appreciation is when a business maintenance model is not effective to deal with the level of unexpected failures resulting from design and construction phase. The planning in production is vital as it allows a clear link between production or operating interval and maintenance interval for optimum quality delivery.

As discussed by (Fakher, et al., 2017), there are multiple methods of optimizing the profitability of an organization from evaluation and optimization of the production plan. The optimization of production plan requires a good baseline from the early stages of the Asset in order for an organization to realize benefits. The isolation of other disciplines when trying to optimize the level of profitability is one of the issues controlled by a business.

The relationship between quality, maintenance, and productivity require a clear definition in a business environment. As stated in (Maletic, et al., 2014), the quality of an Asset has an impact on the performance of the organization which emanates from AOR related issues such as production cost, productivity, service delivery, and work force plan optimization.

4.7.2. Reliability focused Maintenance Strategy

The reliability-focused maintenance such as Reliability Centered Maintenance (RCM) can be very useful to identify the risk of a system or component. This technique of risk assessment uses a well-structured approach, which encompasses

failure, Failure Mode, Effects, and Criticality Analysis (FMECA) of the component as a basis for thorough risk identification. The risk in this approach caters for environmental, safety, and cost related risks (Lofgren, et al., 1991).

There are other risk identification methods within reliability-focused technique, which form crucial tools for identification of the risk similar to FMECA method such as the fault tree and reliability block method (Lofgren, et al., 1991). The understanding of a techniques yields good results in ensuring that there is reliable Asset in operation. The aforementioned methods form part of a qualitative analytic method within the risk umbrella of maintenance.

Reliability centered maintenance has the potential to yield results in accelerated timeline for an organization and this is highly possible if the implementation is efficient and effective, and focused on the right set of equipment (Moubray, 1997). The model has sequential steps, which lead to a decision-making process, and RCM is one of the models that have a clear Framework on how to implement and execute the strategy. Some of the benefits include improvement of performance and reliability, diversity of the model to cater for multiple organizations, and provide the organization with a good database of information related to the Assets.

4.7.3. Computerized Maintenance Management System

Maintenance management has become one of the complex aspects during operation, which has led to many organizations investing huge amount to ensure that there is a well-structured maintenance strategy. The aim of the strategy is to prolong the life of the Asset. The maintenance has multiple considerations which include run-to-failure, time-based maintenance, prevention, CMMS systems, Condition monitoring, and complex methods such as RCM and TPM. Over the year, there are more consolidated methods developed to cater for the rapid changes in technology and maintenance thereof.

4.7.3.1. CMMS Requirement for success

A strategy to avoid failures associated with the maintenance in any industry or organization requires that the six key elements below are considered (Wienker, et al., 2016):

- **The readiness of the Organization:** The organization must always align with the new technology and requirement to maintain that particular technology, and such leads to investment into the right or correct tools to assist with that object and goal. Tools like CMMS always aid in providing the business with the capability to assess the maintenance requirement at a particular point for optimized performance of the Assets or systems.

- **CMMS capability to provide the necessary support**: CMMS has been for some time confused with the maintenance strategy. The role of CMMS is to provide a platform to manage the maintenance activities and requirements, which in turn eliminates most of the human errors leading to oversight in maintenance activities. The ease brought by a well-implemented CMMS assist with effective communication to all relevant stakeholders.

- **The compatibility and readiness of the IT infrastructure**: The business needs to ensure that the IT infrastructure is ready to allow integration of the CMMS system without any major challenges, which might require high capital investment, which fall outside business budget.

- **CMMS benefit for the business:** The benefits which results from a well-implemented CMMS include but not limited to; improvement to business planning and scheduling, ease of data access which leads to proper reporting from the business or maintenance team, control on the spare parts, stock, and tool assembly, and high availability and productivity of the Asset.

- **Change management:** Communication of changes, which reduce human interfaces to all impacted stakeholders, ensures that there is support from all stakeholders in the business. This requires that the change process is well-detailed and well-implemented so that there is a clear Responsible, Accountable, Consulted, and Informed (RACI) framework, clear knowledge and guidelines in

the entire Organization, and ensure that the expectation from the changes introduced are understood by all stakeholders.

- **Resource requirements:** In any implementation or any product, software or system there needs to be a plan, which outlines the resourcing in order to optimize on the utilization and productivity. The resourcing required for CMMS is the personnel to perform the tasks, relevant training, and other items, which can ensure the system is user-friendly.

4.7.3.2. E-Maintenance in an Organization

Maintenance support has become vital for Organization, which operates complex systems. E-Maintenance is one of the support systems, and comprises of several elements shown in Figure 20. E-Maintenance in simple terms is a maintenance support system, which provides the assurance that the maintenance is in line with the operation philosophy and caters for changes or modifications which might emanate from the business (Kajko-Mattsson, et al., 2010). E-Maintenance enables Assets management through a web-based or wireless technology, which in turn has major benefits such as proactive decision-making.

In addition, beside e-Technology, aforementioned, e-Maintenance also covers some of the main maintenance topics such as e-Prognosis, e-Diagnosis, and e-Monitoring which make a business operate effectively (Muller , et al., 2008).

Figure 20 show that e-Maintenance is an involved integrated multidisciplinary support tool to yield the best possible results. CMMS known is a Computerised Maintenance Management System is an integral part of e-Maintenance due to its role when considering the associated functionality and purpose. There are various Organizations, which have invested in tools such as SAP, SPO, and so forth for trying to implement e-Maintenance, and this has been beneficial for Organizations, which enable successful system implementation while considering AOR and elements thereof.

E-Maintenance might appear as a solution for all types of entities but has challenges to consider before implementation. Implementation of e-Maintenance requires that the current system is compatible with the e-Maintenance system requirements.

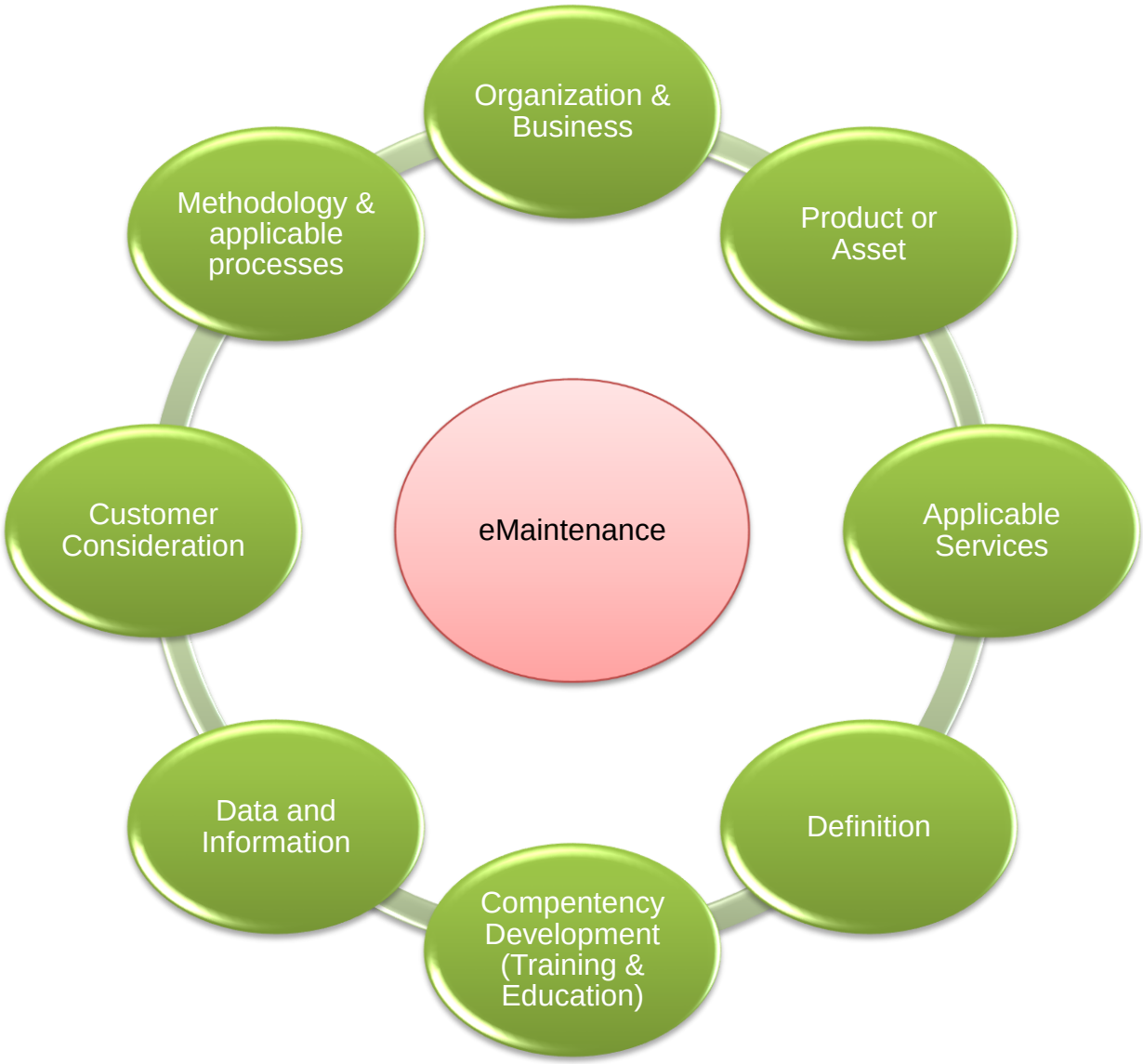

Figure 20: A schematic showing key elements of e-Maintenance, reproduced (Kajko-Mattsson, et al., 2010).

The compatibility challenges might easily lead to restructuring of the entire Organizational systems, changes in the processes and procedures, and major reconfiguration that can be costly. Overcoming such challenges requires a thorough assessment of the e-Readiness, which is the capability of an organization to implement an e-Maintenance system with reduced failures. In addition, drastic

change in technology advancement has led to entities progressing with the modern times by utilizing e-Readiness assessment to cater for e-Maintenance. This effects positive change, which has benefits in terms of competitiveness, optimization in resourcing, optimization of asset life (Aboelmaged, 2014).

4.8. AOR Framework Refinement Tools

The refinement section covers various methodologies necessary for improving the AOR framework. The considered improvement tools include RCA model, and Key Performance Indicator (KPI).

4.8.1. Overview on types of RCA models

The basic RCA methods covered under this section include the “five whys Analysis, Failure Mode and Effects Analysis (FMEA), Pareto Analysis, Fault Tree Analysis, Current Reality Tree, Fishbone Cause-and-Effect Diagrams, Kepner-Tregoe Technique, and RPR Problem Diagnosis.

Apart from the methods aforementioned, there are several other methods not covered in this study, but the few mentioned above does cover the basics of Root Cause Analysis. The basics RCA guidelines by Okes (Okes, 2009) cover significant aspects. The aspects include analysis of event and causal factors, analysis of changes in an organization or environment, analysis of barrier by assessing the controls in place and failures thereof, oversight management and risk analysis using tree diagram approach, and lastly, problem analysis and decision making approach by evaluating the situation, problem, solution, and potential problem.

4.8.1.1. RCA Techniques

The RCA techniques mentioned above aims at highlighting the intent inclusive of, strength, and weaknesses:

- **FMEA or FMECA Technique:** This tool assists in enabling an organization to understand the extent of a damage of equipment and intervene with prevention measures of an identified risk before it occurs. This tool or technique assists to enhance the reliability in a changing environment by ensuring continuous improvement (Andersen & Fagerhaug, 2006). The continuous improvement,

which comes with such a technique enables development of maintenance, plans both reactive and proactive plans.

- **Five Whys Analysis:** This tool is for identifying a problem at hand, and derives a possible solution by analyzing the problem in five consecutive steps, which aims to mitigate the problem from its roots.
- **Fault Tree Analysis:** This technique is for anticipation of problem as means of proactive measures to eliminate the problem before it occurs. In the verge of ascertaining the problems in the process or system this technique uses Boolean logic for a desirable result emanating from the assessed desirable event caused.
- **Pareto Analysis:** This technique aims at understanding the magnitude of the impact due to the causes of events identified. This assessment of causality has chart representation known as the Pareto Chart, which shows the cumulative percentages of the impact, by the selected critical items.
- **Fishbone/Cause-and-Effect Diagrams:** This is one of the most complete techniques for assessing a cause. The analysis of the cause is normally categorized into human factor, process, and physical (machinery, materials, etc.), as well as environment as a minimum to ascertain an effective solution. The interrelationship used to assess the causality makes this technique one of the best industrial RCA tool.
- **Current Reality Tree Analysis:** This technique is applicable in instances whereby the problem occurs regularly, and there is historical data capturing the causes as they occur. The historic events serve as a basis for preventing or troubleshooting the events similar to the ones, which have occurred.
- **Kepner-Tregoe Technique:** This is one of the detailed approaches in reactive risk analysis techniques, which initiates by a thorough understanding of the problem through assessment of the appraisal to ascertain the priority of each cause before an analysis. The analysis seeks to outline the causes of the events and derives the necessary decision list for sustainable solutions implementation.

- **Rapid Problem Resolution (RPR) Problem Diagnosis:** This technique is based on the diagnosis of causes of routine events, and the analysis is based on three items which include data gathering and analysis, investigate through a detailed analysis to diagnose the cause, solution implementation and monitoring. The steps aforementioned aim at assessing the cause and implementation of the solution in a sustainable manner.

All the aforementioned techniques or analysis follow the basic principle of RCA which has four steps as detailed by (Rooney & Vanden Heuvel, 2004). The steps, which are basic in RCA, include data collection, charting of causality, identification of the root cause, and implementation of a logical solution for the event or cause.

- **Bowtie Technique:** Bowtie is one of the analyses utilized for RCA analysis, and this technique is a qualitative risk assessment that is useful to portray the risk associated in a more favorable manner that gives details of the causes and the potential impact.

4.8.1.2. Bowtie RCA Techniques Expansion

The study “Integrating safety management through the Bowtie concept” (Acfield & Weaver, 2012) details Figure 21 in terms of definition of each area in the Bowtie. The study shows that in order to achieve an optimized process, which covers the risk management, management of changes, and investigation of incidents or events, the integrated approach, is of great benefit.

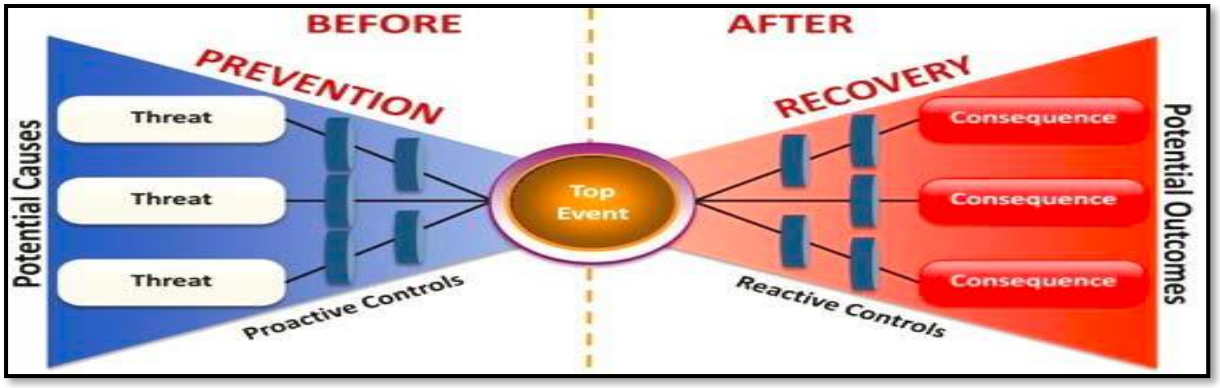

Figure 21: Schematic of a Bowtie showing layout of causes and outcomes (Acfield & Weaver, 2012).

The Bowtie technique is one of the flexible methods used in line with other techniques. The next section of this study gives an overview framework of RCA with multiple techniques. This approach takes into account overall business factors such as physical, human and process. This also ensures that the events assessment with techniques such as “5 Whys” and fault tree for a more profound outcome.

In terms of the RCA relevance in achieving the desired objective for this study, Bowtie methodology has benefits that can be useful to develop the framework, which includes the following (Voicu, et al., 2018):

- Assist in identifying the events that poses a risk to the project and provide a clear understanding of the interrelationship of the events.
- Ability to communicate the relationship between the causes and the effect on sophisticated identified project risks. The risk which are catered for in this technique are covers a variety for all types of stakeholders.
- Assist in giving a perspective on the controls, which can be useful to address the all identified. The major contribution of these controls is its ability to streamline gaps and weaknesses through a well-devised analysis and to mitigate the risks, which exist.
- The technique also covers the human factor of the business, which deals with the ergonomics, interface, and workforce related risks, and how to mitigate through implemented controls.

4.8.2. Project Key Performance Indicator

Organizations have evolved to systematic ways of measuring the performance through a well-structured Framework, and the major contributor to such a stance is the gaps with performance indicators beneficial to the Organization(s). Key Performance Indicators (KPIs) ideally covers all aspects of the business that are critical for its success (Parmenter, 2015). KPI have several areas to consider, inclusive of non-financial measures, timely measures, leadership related, staff related, and asset delivery related, and all in line with Business goals and objectives.

4.9. Project Cost Benefit for utilizing AOR

Figure 22 gives an indication of the benefit of using an AOR model in a PLCM. The project which invests less on the early stages of the project have shown that it has its challenges during the project execution phase due to the instability caused by all the rework and infant failures (Wannenburg, 2016). AOR isolation from the project has implications (i.e. lack of readiness), which leads to project cost overruns.

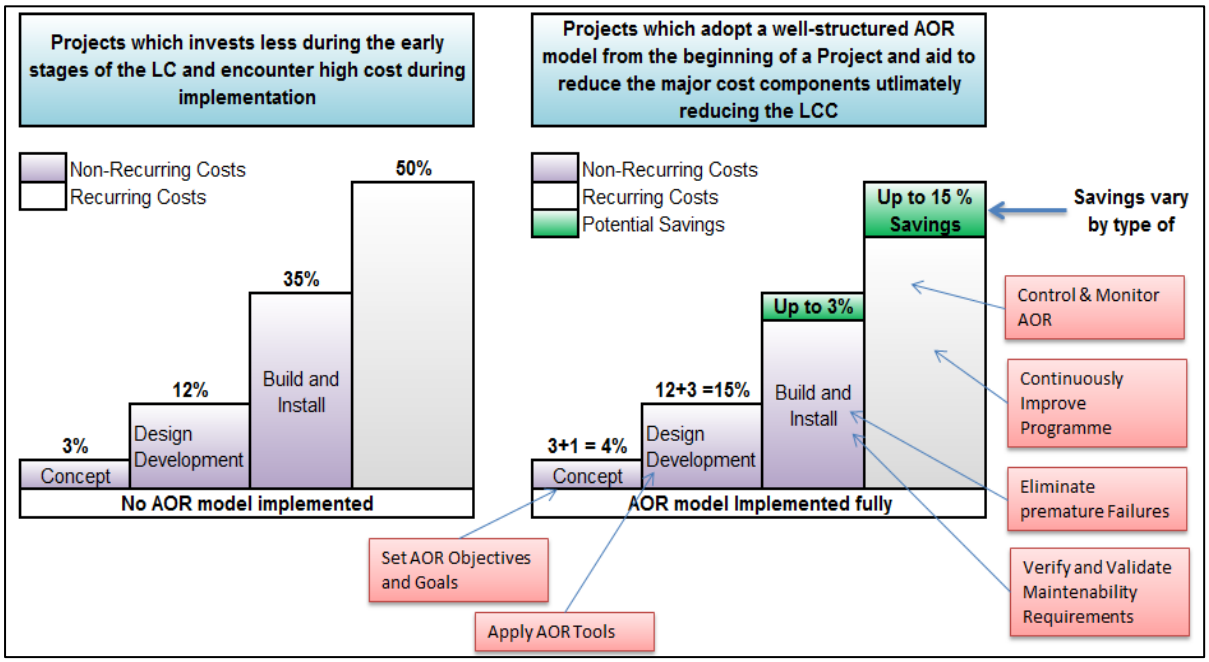

Figure 22: Cost benefit comparison of using AOR against a non-AOR project implementation, reproduced (Wannenburg, 2016).

There are preferable methods such as detailed stepwise processes shown on Figure 17 to Figure 19, which have potential of achieving reduced cost throughout the PLCM. The right hand side of Figure 22 shows an ideal cost saving of up to 15%, which varies, based on the type of project and complexity thereof.

The AOR inclusion in the PLCM gives an advantage in terms of providing a Framework that ensures reduced scopes after commercialization. Implementing the AOR entails that the initial cost of the project will have to increase slightly due to the early intervention and extensive amount of time invested to improve the product delivery processes.

4.10. Literature Summary

This section of the study gives a summary of the AOR practices, various industrial set-ups. It is clear that based on the type of product delivered there might be slight deviation of AOR framework. The main purpose of an AOR framework is to ensure that the end-product delivery is at the right quality to avoid any Maintenance and Operation (O&M) issue, which emanate from the early stages of the project.

The research work covered through the Literature Review provides clarity on the AOR requirements for various industrial fields. The survey shows that AOR implementation follows the PLCM from conceptual and pre-feasibility phase to commissioning and operation phase. The stages of the Asset are as follows as detailed on the literature review:

- Early stages of the life cycle which includes strategy development, planning, and design evaluation. This stage assists in developing a picture of how the final product looks as means of addressing the Business issues. The Asset major features such as materials, performance ranges, and operations environment, have extensive details in design phase. The features give a good basis for estimation availability and reliability of the Asset and serves as a good input towards creating a plan for maintaining the Asset during O&M stage. The AOR framework articulated above gives more insight on the type of strategies required, as well as the specific elements in each PLCM process.

- The construction phase of a project requires the project delivery team to put the plans and strategies to test in order to implement the design. The AOR framework plays a crucial role during this stage as it provides a clear guidance on the process and factors, which can yield good results. The “quality product” creation in this stage of the PLCM need to be delivered to the client at the right time and right cost so that there are no penalties, which tend to escalate the cost of the project.

- The Operations and Maintenance (O&M) stages requires readiness of plans and strategies to optimize production. Optimum operations and necessary retrofits with good maintenance practices will determine Asset life extension for the business to realize its Return on Investment (ROI).

- Decommissioning of the system or component is one of the crucial parts of asset life as it also affects the overall investment cost. Nuclear Power Plant has high cost due to the disposal methods of radioactive material, which have stringent safety regulations.

An AOR framework that gives a more structured model includes all the elements of an asset, which lead to high productivity, and operational efficiency and effectiveness. The area which leads to a successful implementation includes integration of personnel, equipment and system, as well as governance and processes. This is applicable from the managerial level to the operation level in order to yield more benefits form the programs implemented. The process development will take in to consideration the elements such as management support, life cycle design support, maintenance, operations, Organizational requirements and structure, infrastructure, information and technology, and any other processes, which enhance the delivery of final product to optimize O&M.

Maintenance management has become one of the complex aspects during O&M stage, and has led to many Organizations investing aggressively as assurance that there is a well-structured maintenance strategy, which can prolong the life of the Asset. The maintenance has multiple considerations which include run-to-failure, time-based maintenance, prevention, CMMS systems, condition monitoring, and complex methods such as RCM and TPM. Over the years, development of more consolidated methods catered for the rapid changes in technology and maintenance thereof.

Root Cause Analysis (RCA) as a tool that outlines all specific and generic challenges in Organizational processes. One of the considerations for this research study is to understand the causes, which lead to system breakdown from human, process, and physical perspective. This section explores the RCA methodologies that can be used to baseline AOR in any Organization. The basic RCA methods considered include; “five whys Analysis, Failure Mode and Effects Analysis (FMEA), Pareto Analysis, Fault Tree Analysis, Current Reality Tree, Fishbone Cause-and-Effect Diagrams, Kepner-Tregoe Technique, and RPR Problem Diagnosis.

KPI have several areas for considerations, which covers non-financial measures, timely measures, leadership related, staff related, and Asset delivery related. The KPIs formulation will be part of the Business key areas of focus.

The overall project cost reduction requires intervention such as adequate planning, process formulation, and AOR framework development and implementation. The link between reduced project cost and effective delivery of the final product is a well-defined AOR model, which streamlines the quality and completeness validation to ensure that the client receives a defect-free product.

5. AOR THEORETICAL FRAMEWORK

The previous Chapter (4) that deals with the literature review gives an understanding of the requirements to develop an integrated AOR Framework and application thereof. The subsections categorization considers various types of applicable field (i.e. Mining and Oil sector), Organizations, and departments (i.e. DoL). The aforementioned areas provide diverse and different approaches to develop and implement an AOR framework.

The assessed literature review content as well as pictorial representation assist to develop the proposed AOR framework detailed in this section. Figure 23 gives a summary depicting the relationship between the Proposed AOR framework and literature review pictorial representations. The correlation shown on Figure 23 classifies Figures and Tables separately as means of highlighting the applicability to the proposed AOR Framework. In addition, Figure 23 provides clear indication of the content only used as informative data.

The approach employed in developing the AOR Framework provides confidence for the significance of knowledge acquired in the Literature Review. Figure 23 legend shows that there are four colour codes utilized to highlight the importance of the Tables or Figures in the Literature Review. The “main component” shown on Figure 23 groups the AOR components selected as vital for success of an AOR Framework.

The “improvement components” appears on last column of Figure 23 with the necessary details. In addition, the column also shows the areas completely adopted from the literature review content. The “improvement components” added to refine the existing Theoretical AOR framework have been discussed in the literature review for success of a project, but without clear direct relationship towards defining an AOR framework. The inclusion of the “improvement components” provides a more refined AOR framework, which serves as a contribution to the field of science. The secondary improvement to the theoretical AOR framework is optimization of AOR components placement in each PLCM stages.

ITEM #	PROPOSED THEORETICAL AOR FRAMEWORK		Literature Information Utilized for AOR Framework developmental purpose		Not Utilized for AOR Framework development (Only used as informative data)		Improvement Components
	Main Component	Sub component	Figure	Table	Figure	Table	
1	AOR Framework Development & support	AOR Strategy & Project Support	Figure 2: Project Life Cycle Model which indicates the AOR phases. Figure 11: Development Cycle through PLCM, reproduced (43). Figure 12: Operation Readiness interrelated project elements, reproduced (43). Figure 7: Operation readiness competency model (34). Figure 8: Proposal for Process Industry performance evaluation (6). Figure 4: Project life cycle with the ramp-up optimization phase (19). Figure 5: Operation Readiness Capital Project model, reproduced (19). Figure 6: Life Cycle model with the asset handover key stages, reproduced (24). Figure 9: Project Management Operational Readiness key elements, reproduced (24). Figure 16: AOR with integrated sub-areas applicable for various projects, reproduced (23). Figure 17: AOR detailed stepwise process flow for Design and Concept Phase, reproduced (58). Figure 18: AOR detailed stepwise process flow for Design and Implementation Phase, reproduced (58). Figure 19: AOR detailed stepwise process flow for Implementation and Commissioning Phase, reproduced (58).	1. Table 1: Responsible parties in the AOR review process (4). 2. Table 2: Interoperability Composition (42).	Figure 13: High-level process flow showing a stepwise assessment of Manufacturing Readiness, reproduced (46). Figure 14: Railway Acceptance criteria which cover IRL, TRL, and MRL, reproduced (44). Figure 15: Railway Acceptance criteria which cover SRL, SwRL, and RRL, reproduced (44). Figure 22: Cost benefit comparison of using AOR against a non-AOR project implementation, reproduced (57). Figure 3: schematic of a System Effective structure which shown the AOR, reproduced (30). Figure 21: Schematic of a Bowtie showing layout of causes and outcomes (2).		1. Change Management Plan Establishment as means of aligning with AOR Mandate 2. GAP Review Methodology and Mitigation Plan Establishment 3. Review of AOR Implementation & Completeness for improvement purposes
		Manpower Integrated Plan & Training					Adopted from Literature Review
		Information Quality Management					1. Adopted from Literature Review
2	Asset Maintenance Readiness	Maintenance Strategy Readiness					1. Non-Conformance Management input to Maintenance Strategy (refining) 2. Maintenance Cost Plan Development
		Asset CMMS		Figure 20: A schematic showing key elements of e-Maintenance, reproduced (29).			1. Establish System Audit Requirements 2. Process and Data Audit
3	Project Risk & SHE Management	Project Risk & SHE Management	Figure 10: Elements of the Interoperability structure for optimization of AOR (43).				1. Disaster Recovery Plan Establishment and Reviews 2. Progressive Risk Register Update to enable informed Safety clearance and compliance
		SHE & Quality					1. Adopted from Literature Review
4	Asset Life Cycle Value Optimization	Not Applicable					1. Adopted from Literature Review

Legend: Extensively Utilized | Partially Utilized | Seldomly Utilized | Informative Only

Figure 23: Summary of Proposed AOR framework correlation with literature review.

The outputs expected from development of the theoretical AOR framework narrows to five main items as shown on Figure 24, which include detailed AOR framework embedded on a PLCM, maintenance process flow, risk and SHEQ process, skills and competency, and information and data requirement. Figure 24 also shows an overview of the AOR theoretical framework further detailed in this section.

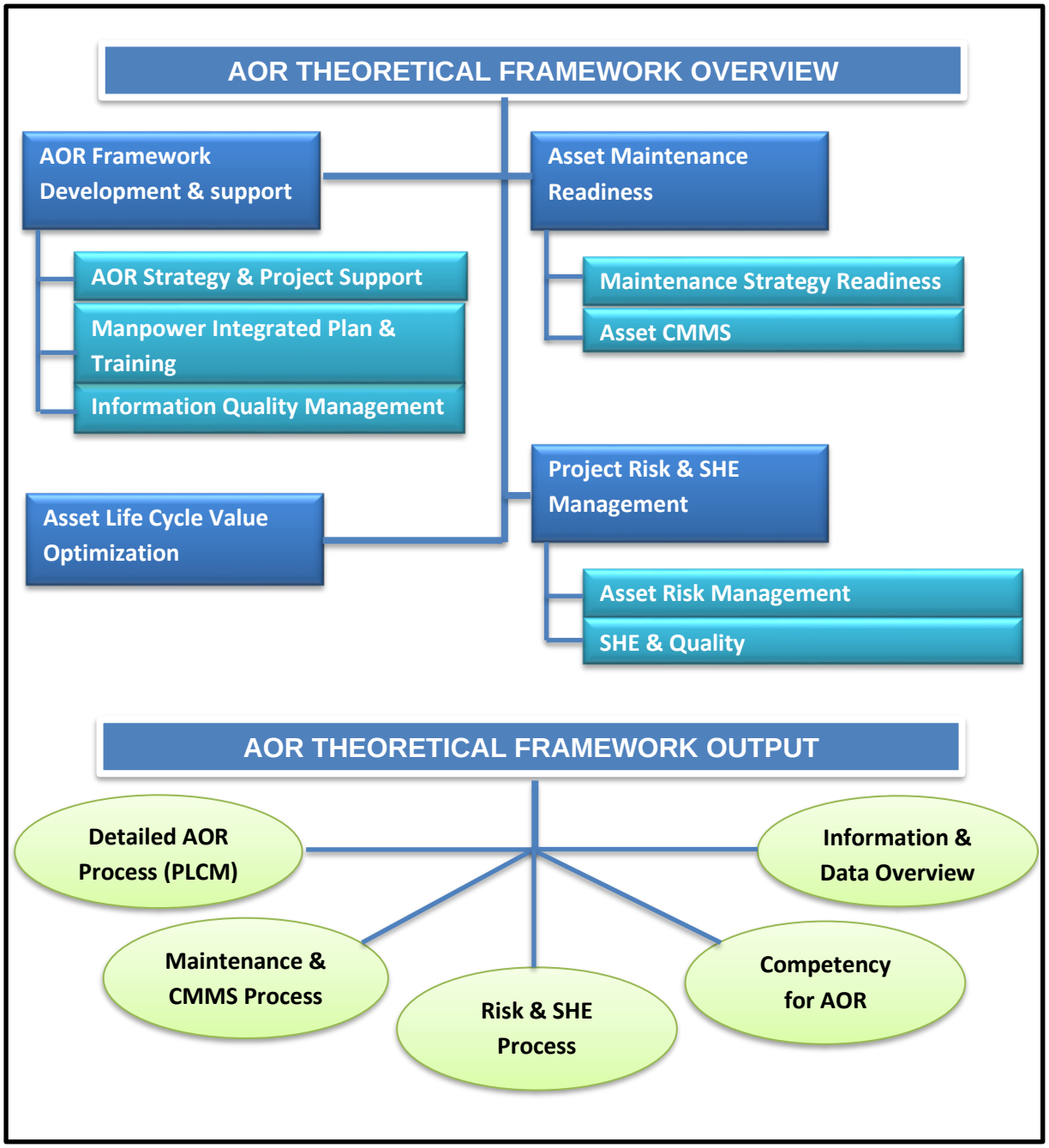

Figure 24: High-level AOR theoretical framework summary and output.

5.1. AOR Framework Development and Support

There are various aspect of AOR implementation to declare as fit for purpose such as ensuring that there are licenses for operating and maintaining some of the explosive system and pressurized systems. The operational readiness of the Organization's asset requires assessment using a detailed risk profiling and safety clearance methodologies, which will provide confidence to the senior management that the Framework approach is adequate to achieve the goals and objectives of the Organization.

The section of the study covers the AOR framework, AOR Support, and Competency to develop and implement AOR, management of data and information, risk requirement, maintenance requirement, and value optimization.

5.1.1. AOR Strategy and Project Support

AOR framework considerations relates to operating modes and process optimization, and RAM of an asset amongst others. this will ensure that when commissioning or taking the assets back to operation post maintenance for refurbishment work or post-handover from the construction and commissioning departments there are no issues, which might result in production losses due to poor quality practices by the personnel responsible for the maintenance or commissioning activities.

The process flow on Figure 25 show a stepwise approach to achieving an effective AOR implementation. The colour coding relates to different dimensions of AOR development. The components highlighted in lime green colour depict the management role for sourcing funds used to sponsor the development and execution on the AOR strategy. The funding finalization takes place in the definition phase of the PLCM as shown on Figure 25. The AOR strategy will require support which includes competency establishment (highlighted in light blue), resources and IT related support (highlighted in orange), RAM study oversight (highlighted in red), GAP analysis establishment and mitigation measure which are employed in closure of punch items (highlighted in light orange), and lastly, the core AOR framework components which are (highlighted in blue colour).

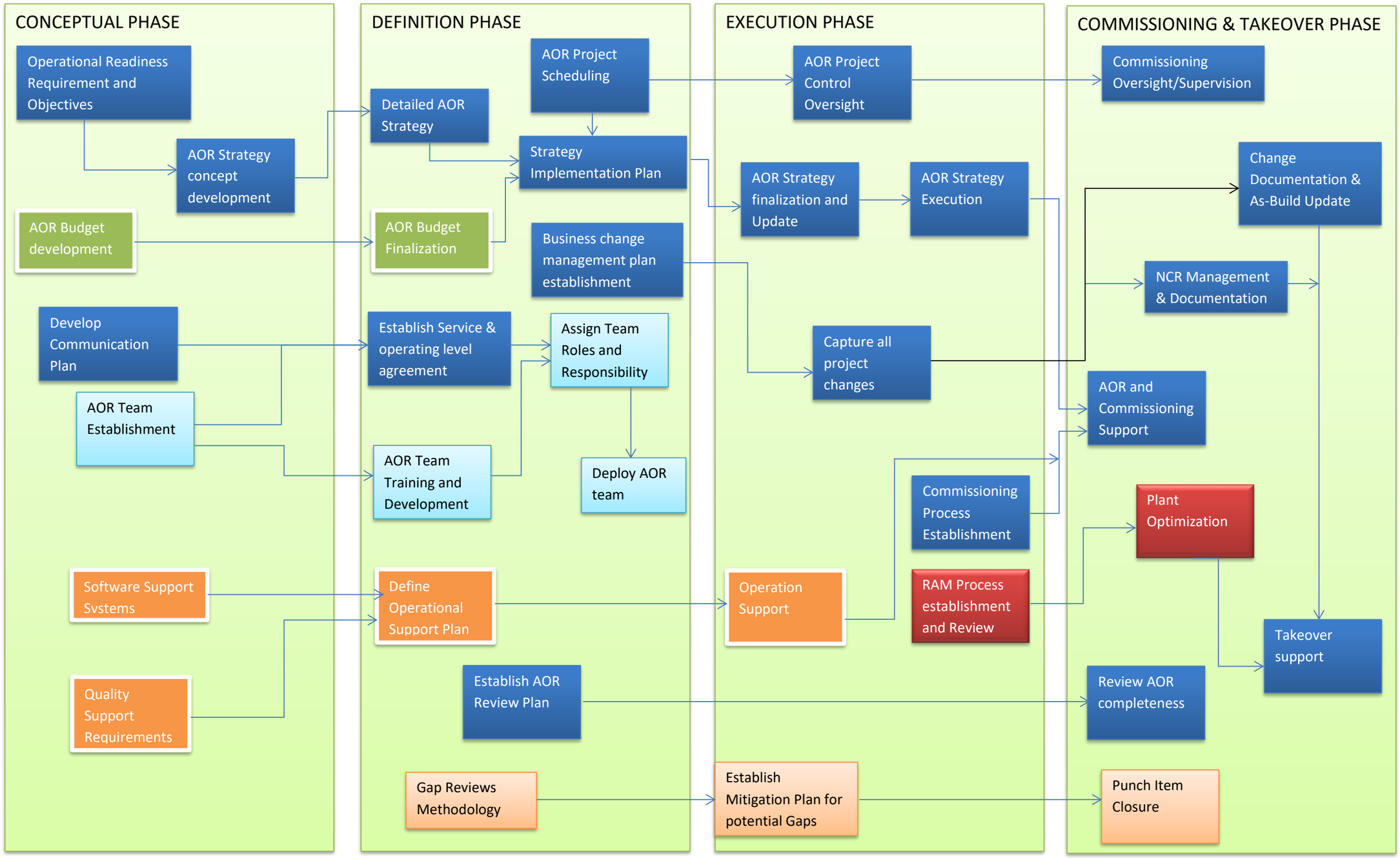

Figure 25: AOR and support detailed process flow.

5.1.2. Manpower integrated Plan and Training

The Organization needs to consider detailing the areas, which require attention for ease of resource optimization. The number of personnel and skill-set deployment requires knowledge of the complexity of the technology. A technological inclined system will be costly with a guarantee of a well-defined maintenance approach that requires reduced resources for Operations and Maintenance (O&M). A less sophisticated technology might lack some capabilities and entails that more resources will be required to perform inspections on a regular basis during O&M.

The Asset development or maintenance approaches will assure that the business has good Returns on Investment. A sophisticated approach entails that non-critical system or equipment will require condition-monitoring maintenance. Such consideration in some departments or areas might be an unnecessary intervention. The aforementioned complexity should consider a work force plan that might yield the required outcome. Management should take into account the following as primary means of ensuring an effective AOR strategy implementation:

- Estimation of headcount for the preferred for the AOR activities which will ensure that there is a team in the field of mechanical, electrical and instrumentation controls, civil and structural, process and optimization, safety and environmental, and design and drawing redesign.
- Implementation cost breakdown for each personnel as per the Organization's grading.
- The hour utilization of each personnel based on a 40 hour per week. The exception of overtime as a contingency for unplanned outage and weekend planned shutdowns.
- The work force plan will ensure that there is clear indication of roles and responsibilities for all relevant stakeholders.

The organization has a better control of the activities if there is a well-defined plan for work force to execute tasks and activities. There are several aspects of resource optimization and resource planning which to consider as listed below:

- The resource plan must ensure that it caters for the skill needs of an organization to an extent that it is convenient when performing maintenance and operation activities without any hindrances.

- The resource breakdown can be a combination of both internal and external resources with the skills categorized from the graduates or juniors to the experts. This entails that a well-define study needs to be conducted to ensure that the required capabilities are embedded within the implemented resource strategy.
- The core capabilities will have to be either out-sourced or developed through the Organizational development and training structure. This requires financially feasible approach to ensure that there are no cost overruns affecting business profitability.

Lastly, the demographic resource study will have a crucial role to assure the business that it can source skills out of the country without upsetting the communities within the radius of the Organization.

5.1.3. Information Quality Management

The management of information is one of the major factors, which the organization needs to pay much attention to as this provides necessary data to be used for integrating activities done by each stakeholder. This also enables the management to make informed decision. The information needs to have the correct capturing and archiving systems, which includes computers, central hubs accessed by all personnel, library or workspace, correct tools and software, and so forth.

The quality management will have to be one of the major considerations to ensure that there is correct data management, system management, and quality assurance in according to ISO standards. A good quality practice goes a long way in an organization as it reduces unnecessary expenses, which compromise the principle of having a well-defined budget plan for sustainability of the business. This ensures that there are quality assurance plans and quality control procedures used for justifying the standard of maintenance activities, and form input to development of internal staff

5.2. Asset Maintenance Readiness

The maintenance department, which will be the custodians of the maintenance business strategy, needs to take cognizance of the historical Operational and Maintenance (O&M) risks faced by the organization over the past decade.

5.2.1. Maintenance Strategy Readiness

Sufficient input data to inform the maintenance strategy development and implementation is important for establishment of an AOR framework. Years of historical data will provide a good basis for upfront planning which the maintenance team needs for improvement of the maintenance strategy.

Figure 26 shows a typical high-level process for maintenance consideration, which applies to various sectors. It is clear that a well-structured maintenance process requires good management support in order to ensure that the execution team has all the tools necessary to fulfil their duties. The block highlighted in red show the elements to consider in a maintenance philosophy, while the green colored blocks shows the necessary support required as success of a maintenance strategy.

There are challenges, which lead to project execution failures; hence, a requirement to develop AOR framework as a measure to alleviate unwanted events in a PLCM. The following provides challenges to various businesses that should be eliminated a well-defined maintenance process flow as shown in Figure 26:

- Planning without the collection of historical data to make informed maintenance decisions.
- Financing unplanned maintenance projects which are required for assets or plant equipment performance. This affects the business cash flow and leads to production ineffectiveness.
- Issues with monitoring overall energy consumption that affects annual costing for purpose of budgeting. The cost of energy consumed by the equipment has been limited to major component in most businesses. This brings a challenge if the low-rated energy consumption equipment has been isolated from the total energy

consumption tracking, and this has a big implication because of the number of the small components.

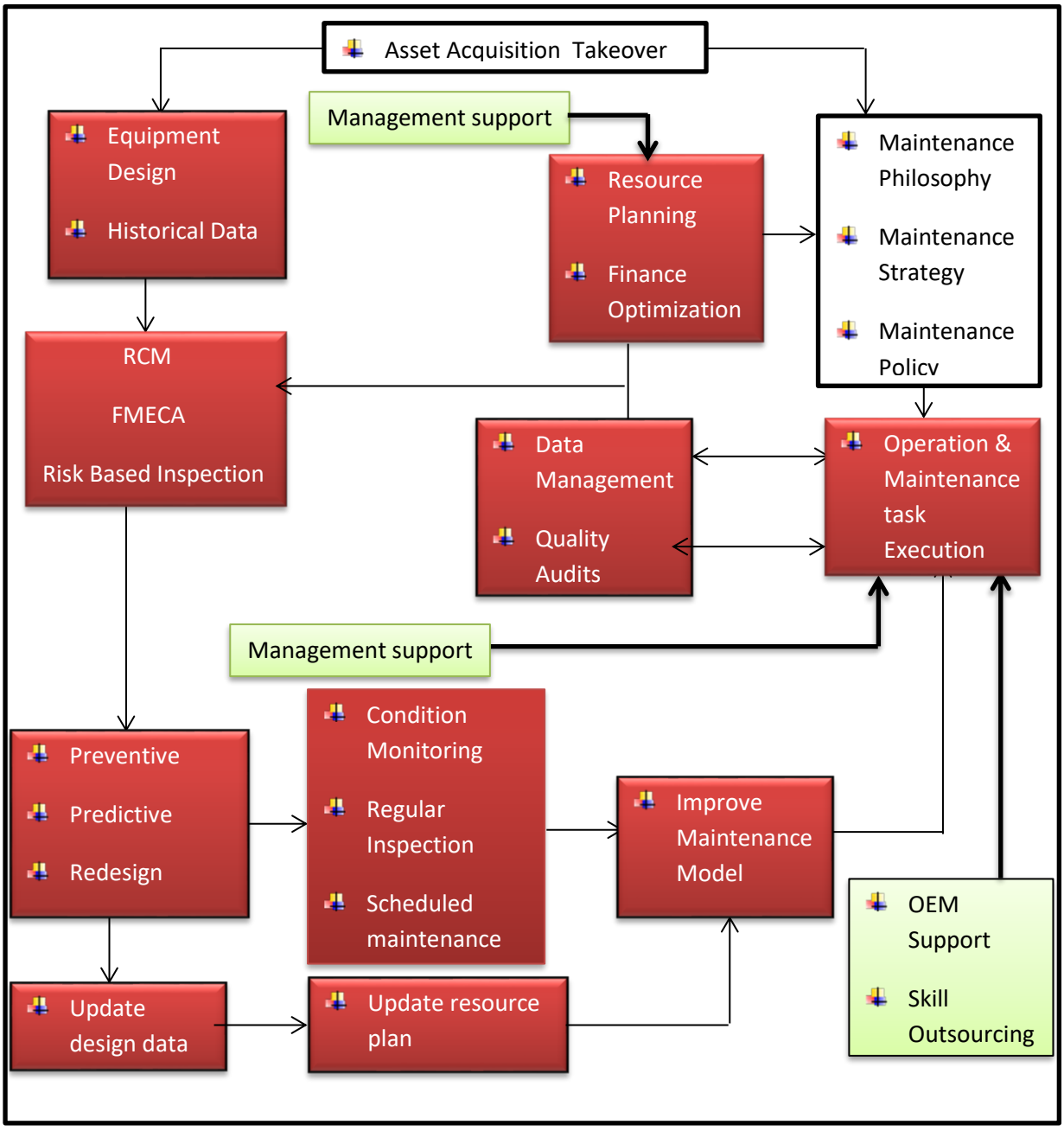

Figure 26: Maintenance Philosophy flow diagram proposed.

- There are premature failures of equipment during operations resulting from lack of skills and knowledge of the Operations and Maintenance (O&M) team. This is a major blow for several Organizations since it has high implication in terms of legal, financial, and safety perspective.

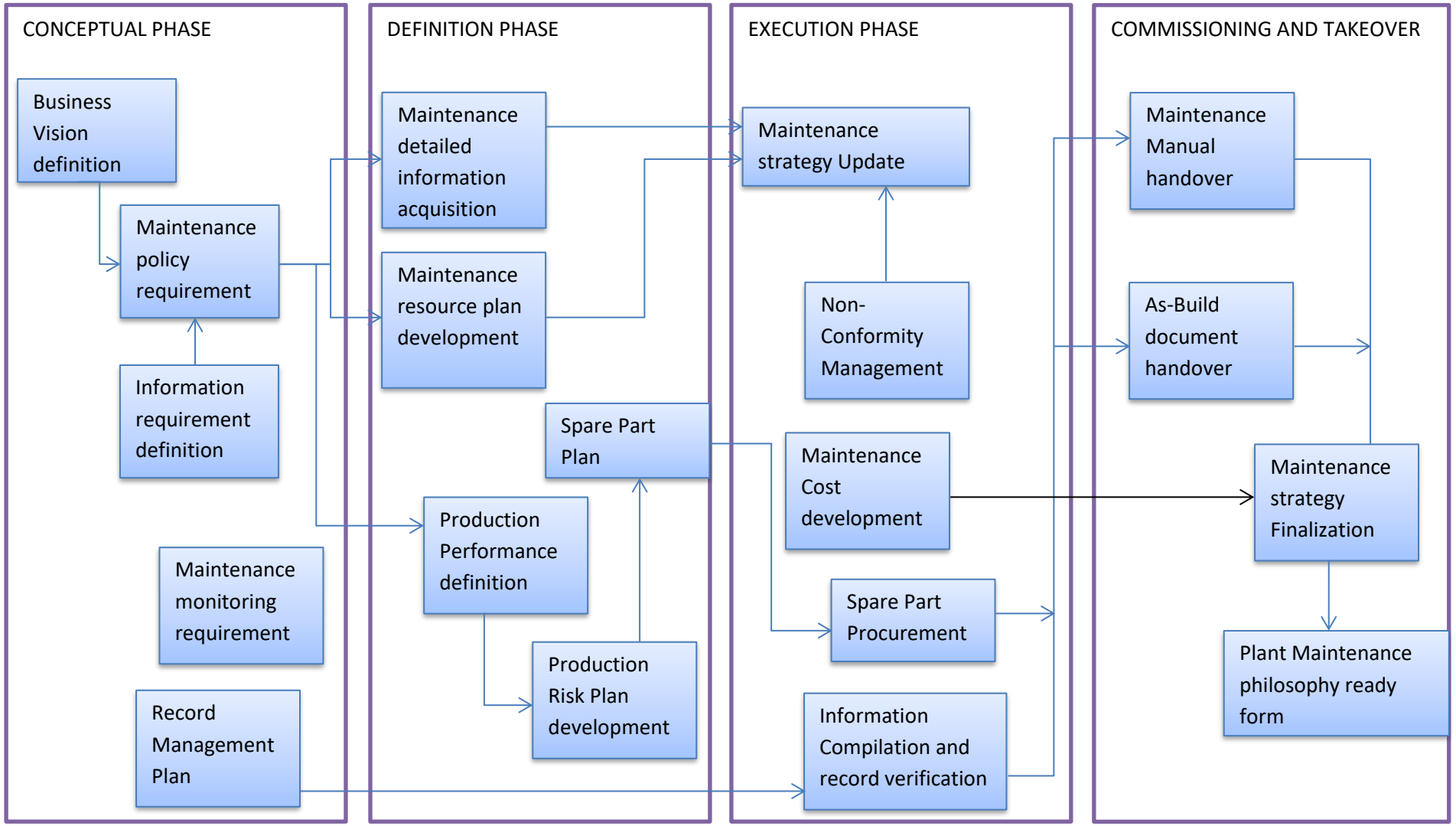

Figure 27: Maintenance implementation process flow.

- Control interventions, which are not adequate to minimize the failures. This has leads to many shutdowns, which affected negatively on the productivity of the Organizational assets. Such events need intervention from the senior management. In addition, some of the controls do not take into account the design, construction phase related issues, which influence some of the failures.

Figure 27 depicts a maintenance implementation process from the concept phase to handover phase. This gives guidance on how to implement a maintenance readiness process in the Business. The process flow also gives insight on the requirements to meet a maintenance ready environment. The elements shown on Figure 26 and Figure 27 are crucial for the sustainability of the Organizational asset throughout the operation life.

5.2.2. Computerized Asset Maintenance Management System

Operations and Maintenance (O&M) management system incorporate mandate and vision of the Organization, which is to ensure that the Assets yield the most Return on Investment and provides the service required through its entire life cycle. Plant or equipment design uses standards and quality governed by international best practice. This entails that each organization needs to develop a structured document, which will ensure that there is proper integration of the applicable standards to the design changes, which might emanate from a need to re-design in future.

The organization's project requires multidisciplinary teams, which can execute the maintenance scope of work effectively and efficiently. Figure 28 shows the required business maintenance structure which the senior management needs to consider for maintenance practice within the organization. The process details the stepwise approach which should be followed to achieve the CMMS strategy which can be utilized during operation tom manage the maintenance activities. This runs through systems such as SAP or other management system with the correct capability to achieve the required output.

The proper oversight from the organization will enables a more structured handover process for current running projects and future Asset enhancement project, which

will result in the correct technical documentation for maintenance of the equipment. The documentation includes design documentation, as build documentation, system Operations and Maintenance (O&M) documentation, commissioning documentation, and so forth, which guides the operating team and the maintenance team on the relevant changes, details of the Asset, and activities for acquisition and commissioning.

The structure also emphasize on an effective maintenance process that will require that the business optimize management support in order to ensure that there are no gaps between the different teams and stakeholders. There should be emphasis on the management support specifically on the area of resourcing, financing, operation, and maintenance task execution as this is the area, which requires most attention. The resourcing needs to have the right skill-set for the process to be effective during its implementation.

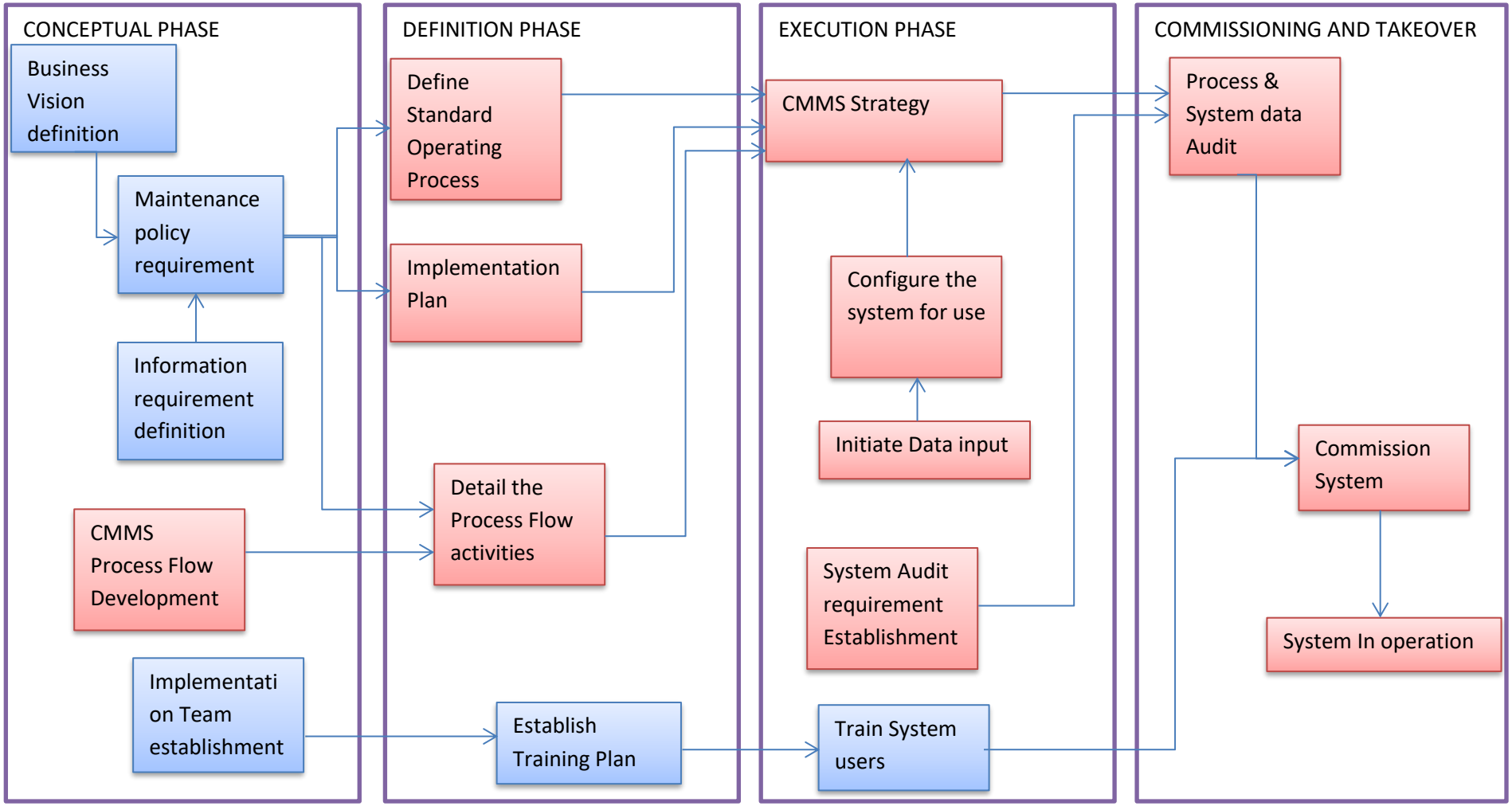

Figure 28: Computerized asset maintenance management system process flow.

5.3. Project Risk and SHEQ Management

An organization will have to invest on multi-technique for profiling the risk of the engineering assets, and this is because each method (such as FMECA, RBI, RBM, etc.) has its own role within the maintenance space. The section of the study gives insight on the envisaged risk management as well as SHEQ.

5.3.1. Asset risk management

Figure 29 gives more insight on the relationship between the different techniques, to utilize for achieving controlled risks during operation.

The expected outcomes of the structure depicted in Figure 29 is a well-defined profile of all the risks associated with the Assets, improved reliability, improved availability, and improved maintainability. In addition, the structure also promises improved quality assurance and technical integrity of the system over the expected life of the asset. The implementation of the system or process below leads to an enhanced safety, health, and risk management to reduce any undesired impact.

The implementation of the maintenance processes will prolong the life of the equipment as it adds value and assist with critical decision making which will save the organization money in both short term and long term.

The implementation is not a standalone but rather a puzzle, which requires continuous improvement to ensure that equipment, performs adequately. Continues improvement takes place through regular audits and regular performance monitoring. The performance monitoring and audits will ensures that the system meet the requirement of the drastically changing technological environment.

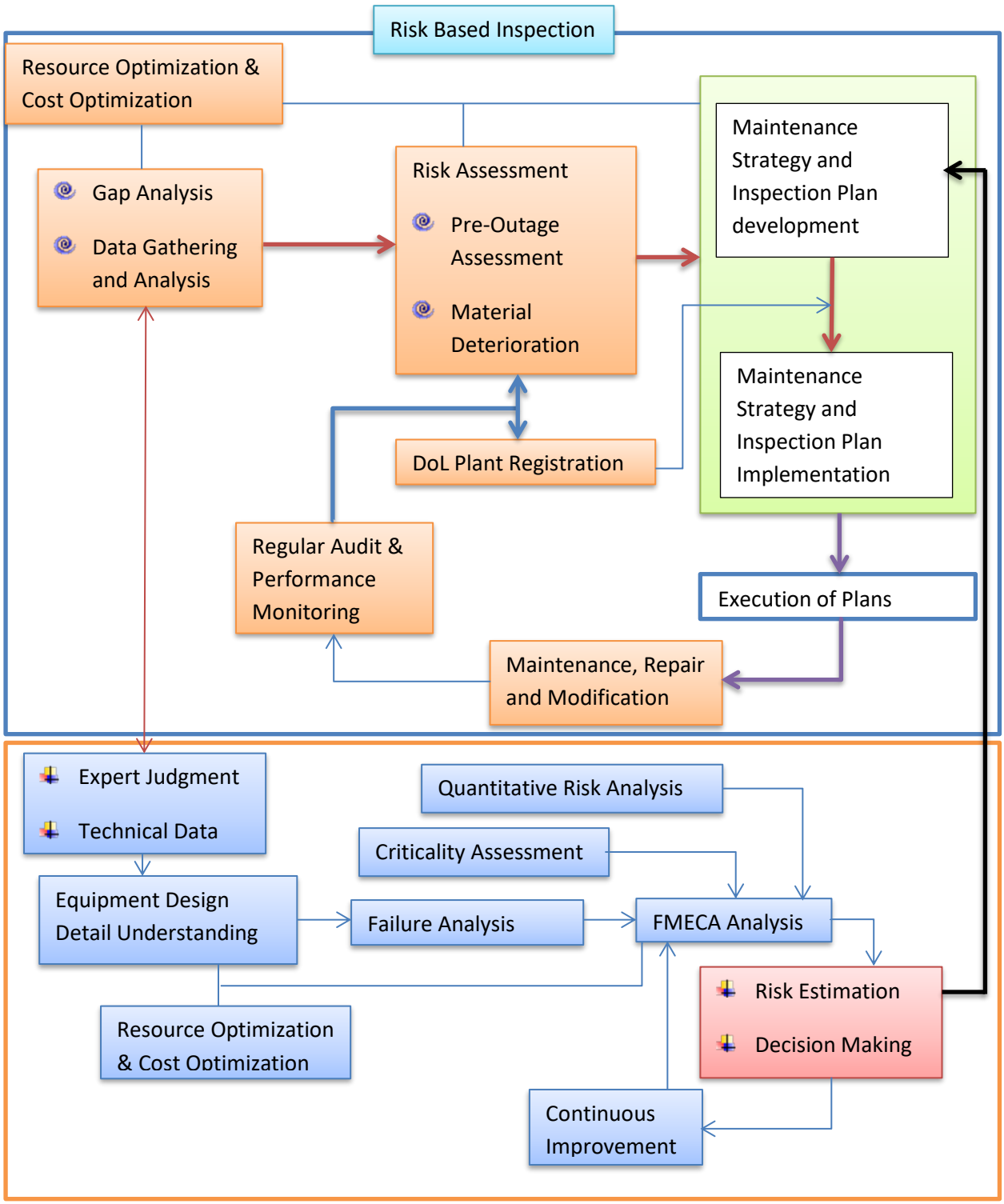

Figure 29: Risk profiling through the life cycle for adequate maintenance flow diagram proposed.

5.3.2. Safety, Health, Environment, and Quality

During design and implementation phase of the project a business needs to conduct its tasks and activities according to the highest occupational, safety, health, environmental, and quality standards to avoid violation. Violation in this regard leads to revoking of some licenses, as well as fatalities or incidents. The structure required to achieve a well-defined SHEQ model should follow the international standards practice, as well as the adopted Organizational processes and procedures.

The implementation of the design requires controls in an environment for safe execution of the works, and this achievable by having the right safety personnel providing supervision. There are non-compliances to some of the requirements, which have led to property damage or injuries or even fatalities. To ensure that the hazards are reduced or eliminated the design has incorporates the safety directives, international standards, and South African standards as a mitigation measure.

The Business policy shown on Figure 30 is required to compel the personnel to adhere to the directives in order to lower the risks, which could compromise safety of the Organization. In addition, there are other measures such as recycling of worn equipment or scrap material, housekeeping, and cleaning activities, which ensures that the environment and safety is not impacted, and this applies throughout the project life cycle.

Figure 30 gives guide on how to implement the SHEQ and risk methods within a business. The stepwise process requires consideration as it combines best practice approaches.

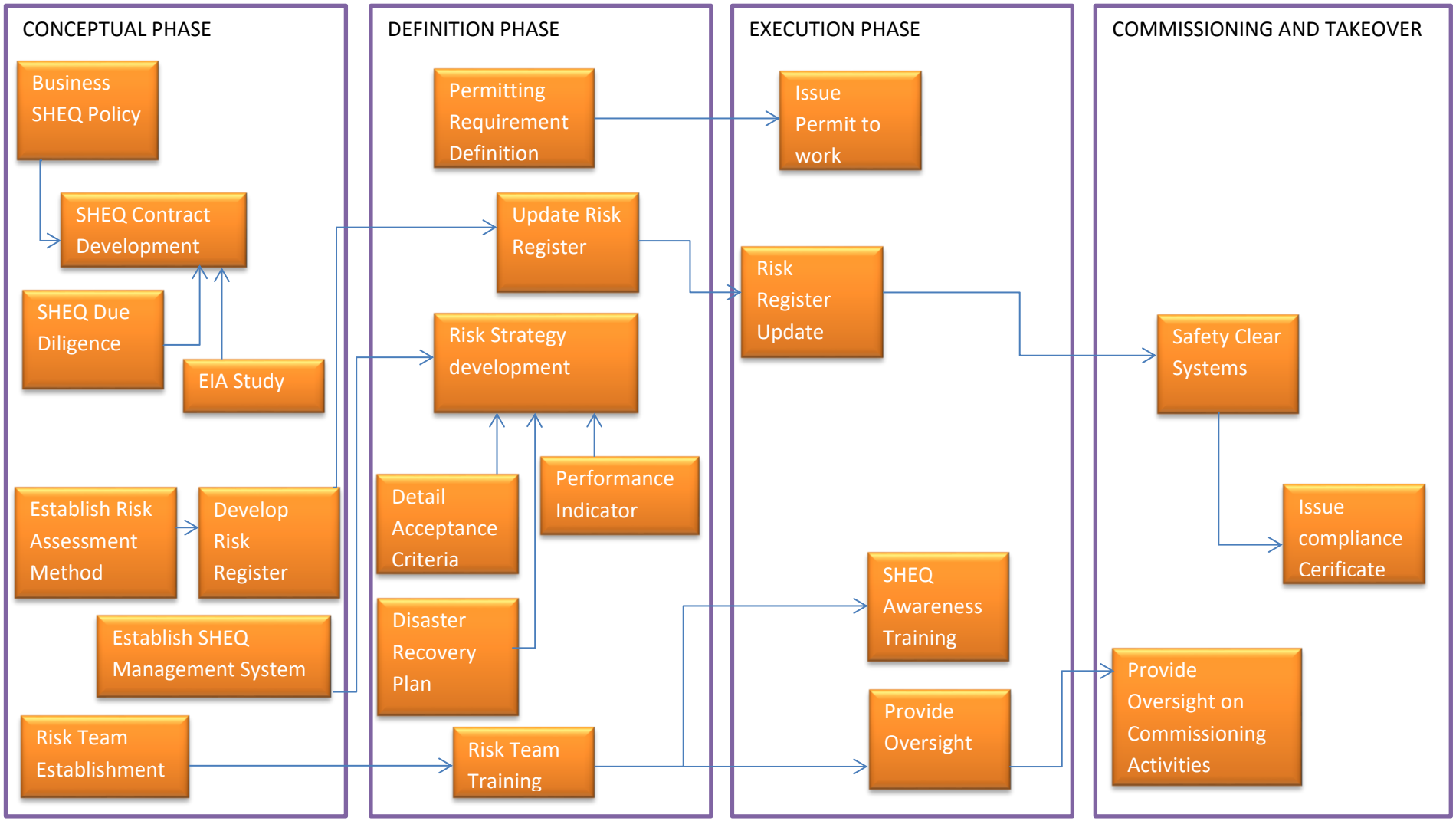

Figure 30: SHEQ and Risk Management process flow.

5.4. Asset Life Cycle Value Optimization

Asset value realization in an organization will take into consideration the value risk exposure, long-term sustainability of acquiring, and Operations and Maintenance (O&M), and disposing of the Assets. The sustainability will focus on the Asset utilization, social impact, stakeholder relationship, performance optimization, and safety and environmental. This is achievable by having a structure, which aims to optimize the value of the Asset over the entire life cycle. This varies with different Assets because there needs to be several decisions or stance, which the organization has to take.

The asset optimization aligns with mandate of the organization to provide a quality service at a sustainable manner to a client. The Asset in the project has been design in such a way that it is easy to operate by the skill-sets or manpower within the Organization, and this has been achieved by integrating the control and instruments of the plant with the central control system in order to manage the entire activities of the assets during operation. This readiness aspect of the AOR needs to consider the value cycle of the assets as this involves value realizable from the utilization, which has exceeded or in line with the expected availability and reliability required, and during the available time, the Asset should fulfil the demand and required service or output.

Maximizing the value of the asset requires integration between all the elements of Asset Readiness and this means that if one of the elements does not meet the necessary requirement, the AOR strategy is incomplete to meet organization’s expectations.

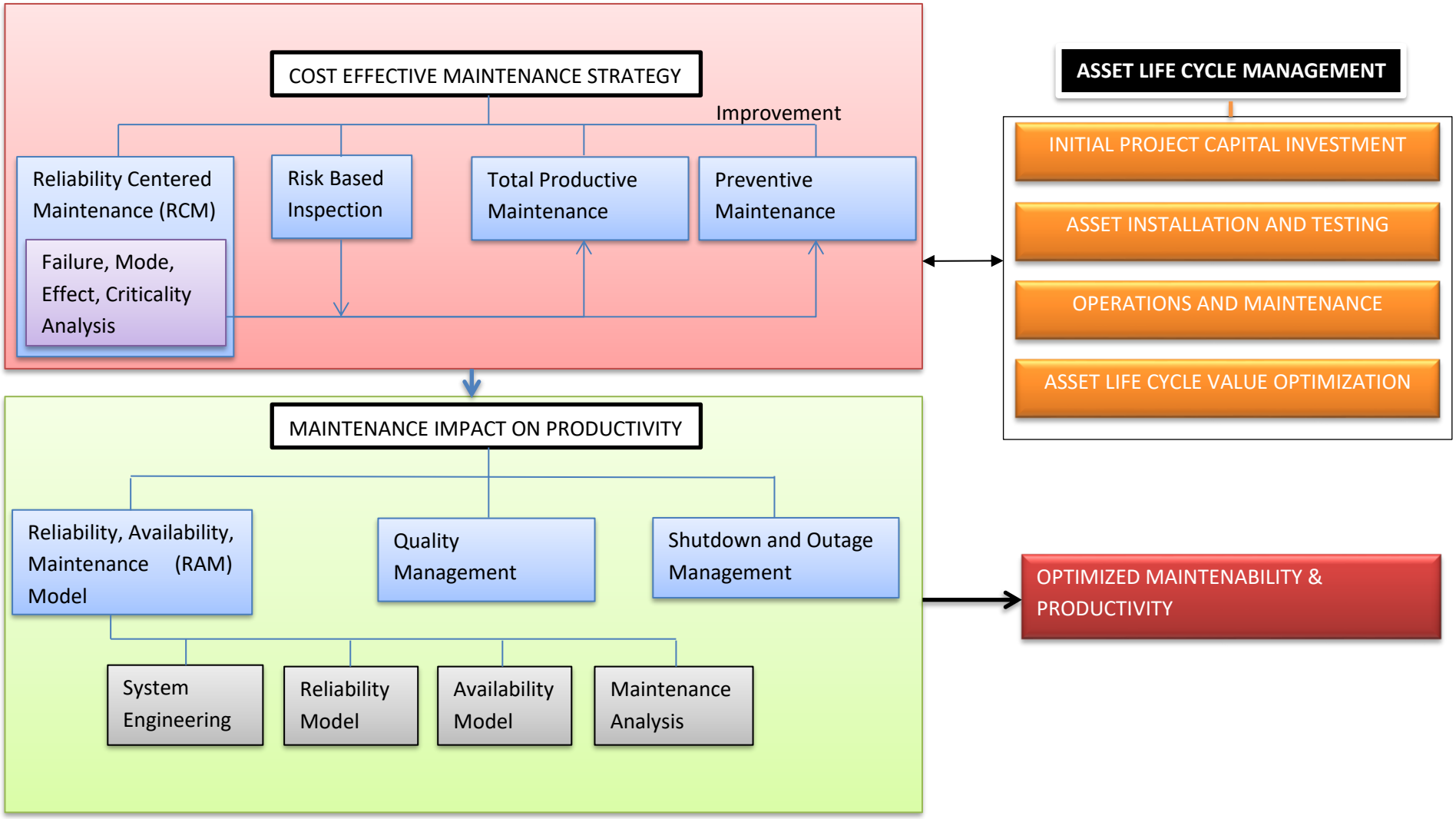

Figure 31: Effectiveness and efficient production implementation process.

The process in Figure 31 depicts link between an integrated maintenance structure on top and maintenance impact on production shown below. Effective maintainability and productivity of an Asset lead to improved and reduced maintenance cost, and improved production and operation cost which impacts on the overall Organizations' profitability.

The interrelationship of all the factors indicated in Figure 31 is required to have a sustainable outcome during operation. The sustainability emanate from quality product, optimization during operation, and accuracy in Reliability Availability Maintainability Studies (RAMS).

6. AOR THEORETICAL FRAMEWORK REFINEMENT METHODOLOGY

The section of the study provides an outline of the refinement methodologies used as input in the AOR framework application chapter. Figure 32 gives process flow for the link between the AOR framework applications, refinement, and literature review. The refinement methodology covers various aspect of the AOR framework, which includes;

- The preparation of the AOR Assessment tool to ascertain the state of project readiness on specific case studies conducted.
- A well-defined qualitative survey questionnaire assists with the interviews.
- Embedding the AOR assessment tool with the scoring system as means of distinguishing the least performing category of AOR in a specific case conducted.
- Multi-techniques RCA Model development for identifying challenges which might be difficult to detect with the use of a theoretical AOR framework. This provides an opportunity to improve the AOR framework in line with real-life project events. Figure 32

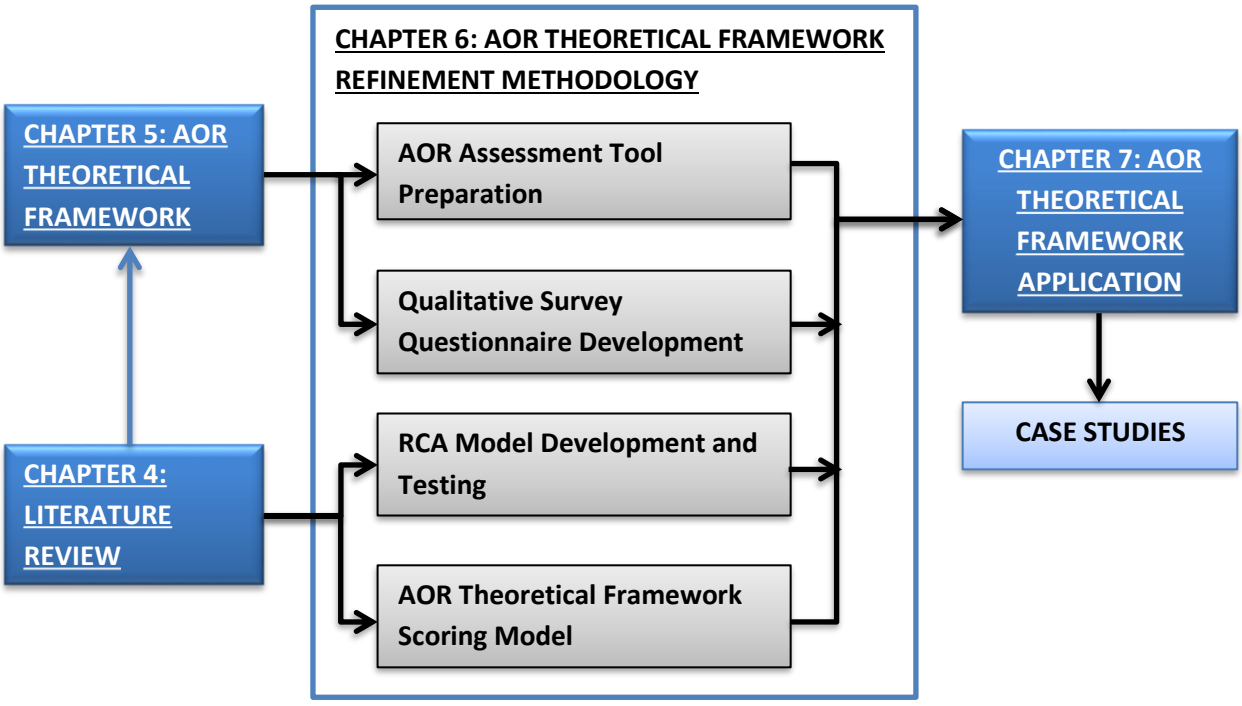

Figure 32: AOR theoretical framework refinement methodology process flow.

6.1. Root Cause Analysis Tool

The Root Cause Analysis (RCA) adopted in this section as a proposed refinery for AOR framework is a consolidation of multiple RCA methods namely; fault tree analysis, 5 whys analysis, Bowtie analysis, fishbone technique, and Kepner-Tregoe Technique. The multi-technique model demonstration uses a detailed analysis of an event, which has taken place within the selected Organization. The proposed RCA methodology implementation will be on the case study to ascertain the causalities that led to the primary event identified. The techniques aforementioned might not necessary feature in each case study due to the uniqueness of each event. RCA assists to communicate to an organization on areas, which requires improvement or management intervention.

The intent of this activity or analysis is to establish failures or events to aid with optimizing or improving proposed AOR theoretical framework.

Figure 33 shows a real-event RCA, which comprises of four techniques used to analysis Pulse Jet Fabric Filter (PJFF) fires (event). The techniques which are applicable to this specific real-event and have been explored include Kepner-Tregoe, Fishbone, Bowtie, and “Five whys” analysis.

The Analysis Figure 33 shows a sequence of failure events that require well-defined controls as prevention or mitigation measure. The analysis is broken down into three main categories, which comprises of human failures, physical or machinery faults, or failures, and process related failures. These categories assist to assess the events, which could have led to the primary event (i.e. fires on the PJFF). The events in each category have a direct relationship to the other events on other categories.

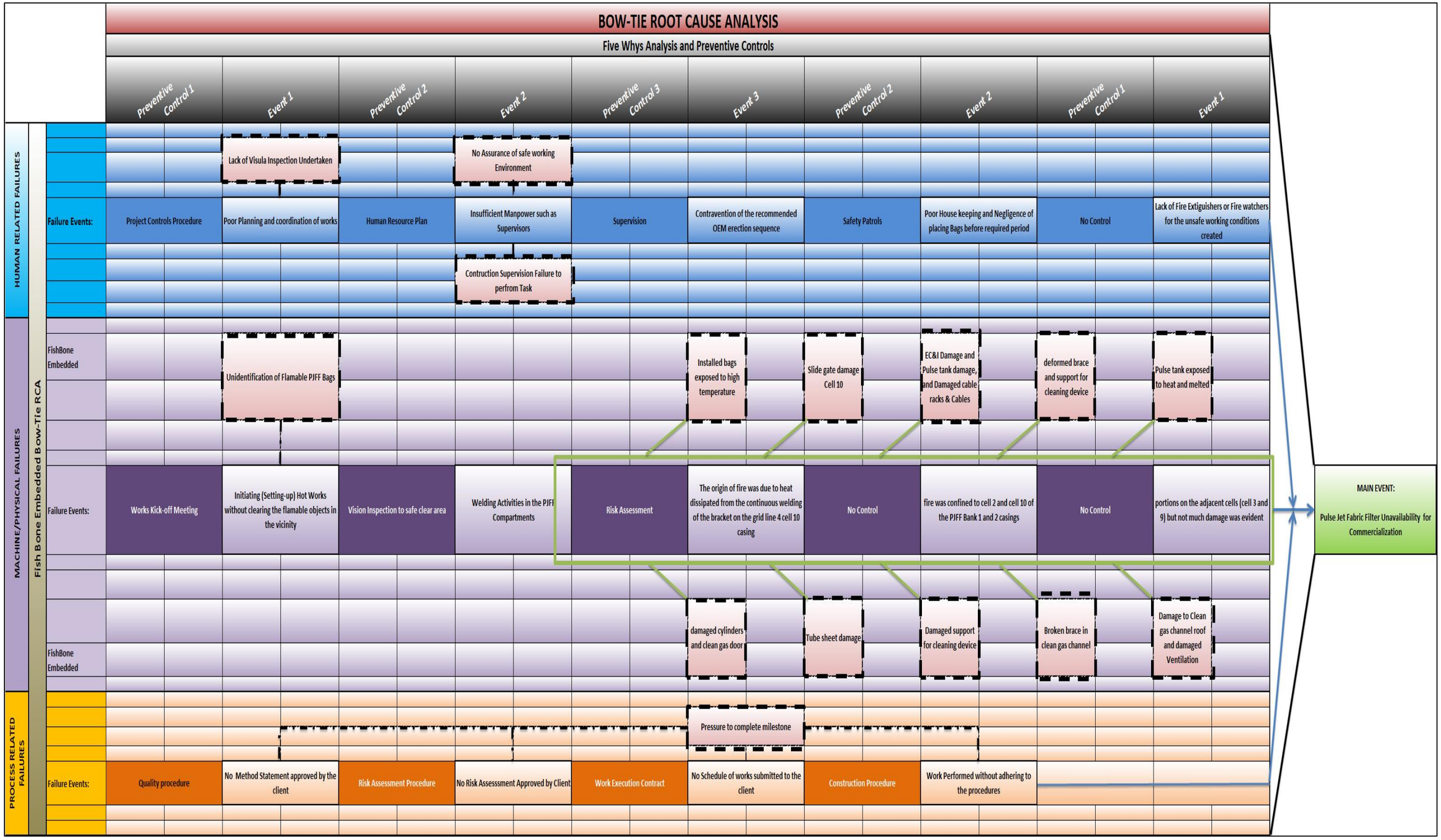

Figure 33: Proposed Bow-Tie Model with Embedded Fishbone and Five Whys RCA conducted on PJFF Fires.

6.2. AOR Framework Case Study Assessment Classes

The processes detailed in AOR theoretical framework section assist to create tables shown below. Table 3 to Table 7 shows the AOR framework assessment tools derived from the AOR framework processes flow, proposed above. The intent of the conversion of the processes to the tabulated framework is for the purpose of the assessing the project or Organizational planning and execution of new build Power Plant projects. The assessment using the tables below is broken down into five classes as shown on Table 3 to Table 7.

The classes used for categorize AOR functions in an organization are as follows;

- Maintenance planning and implementation,
- Maintenance computerized system which tries to drive the organization to the industrial revolution of e-Maintenance,
- Risk management through the AOR involvement,

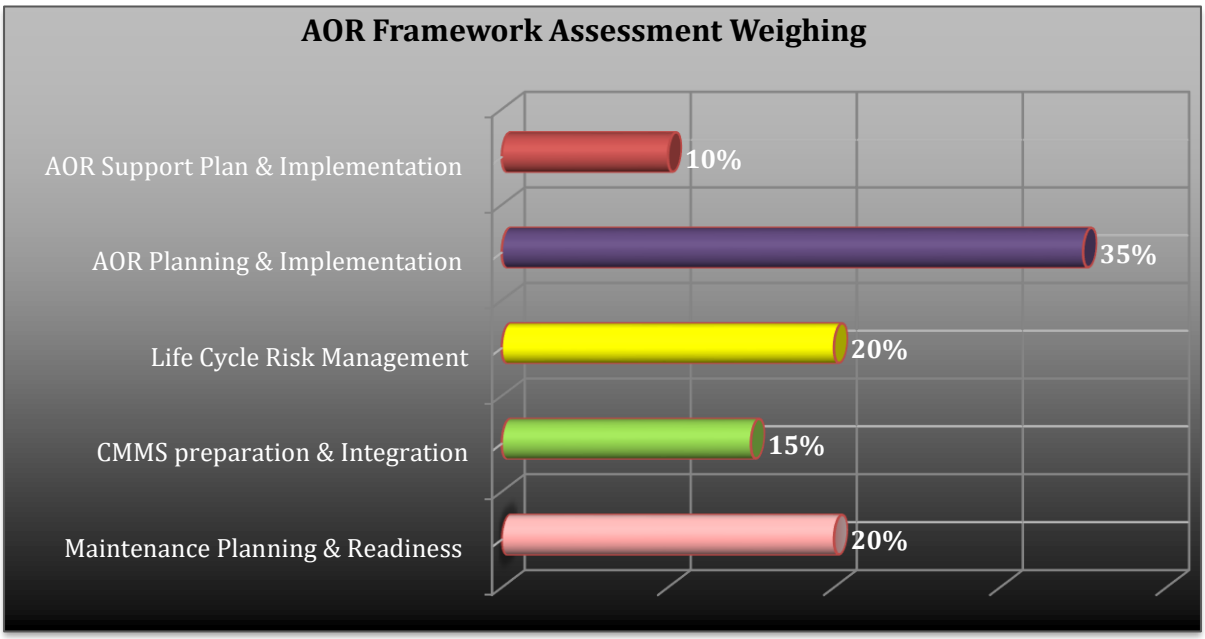

Figure 34: AOR framework class categorization with individualized rating.

- Skill, competency, and support drives to ensure that the organization is ready to assume Operations and Maintenance (O&M) of the Asset,

- The core element, which is AOR strategy development and Implementation in order to ensuring that there, is well-defined stepwise approach aimed at delivering the final product.

The embedded classes with a proposed weighing takes into account the Literature Review, RCA assessment, and components of the proposed AOR framework processes and significance thereof.

Figure 34 depicts the weight allocated to each class with support and e-Maintenance system (CMMS) having the lowest influences the final assessment score. Maintenance philosophy and risk management have the same influence at 20%, and lastly, AOR strategy has the highest influence, which shows the significant in terms of the impact with 35% allocation.

Item #	Item Description	Operational Readiness Planning and Implementation (Weigh 35%)											
		PROPOSED METHOD											
		Conceptual Phase			Definition Phase			Execution/ Implementation phase			Commissioning /Takeover Phase		
1	AOR Strategy	AOR requirement and Objectives conceptualization AOR Strategy Concept Development			Detailed AOR Strategy Development Strategy Implementation Plan AOR Business driven changes Management Plan Establishment AOR Review Plan Development			AOR Strategy Finalization and update AOR Strategy Execution Commissioning Process Development Recording of Project Changes RAM Process Establishment and Review			Takeover Support AOR and Commissioning Support Change Documentation and As-Build Updates NCR Management and Documentation Review AOR Completeness Plant Optimization and Operation threshold establishment		
2	AOR Funding and Budget	Funding and Budget Establishment			AOR budget Baselining								
3	Communication Structure	AOR Communication Plan Development			Establish Service delivery agreement Establish Operating Level Agreement								
4	Gap Analysis				Gap Reviews Methodology Establishment			Establishment of GAPs Mitigation Plan			Closure of Punch Items		
5	Monitoring and Control				AOR Project Scheduling			AOR Project Control Oversight			Oversight and Supervision of Commissioning activities		

Table 3: AOR plan and implementation readiness assessment class.

Item #	Item Description	Maintenance Planning and Readiness (Weigh 20%)								
		PROPOSED METHOD								
		Conceptual Phase			Definition Phase			Execution/Implementation phase			Commissioning /Takeover Phase
1	Strategy Development	Business Vision Definition and Project Charter Development Maintenance Development Initiation			Maintenance Resource Plan Development Production Performance Detailing Production Risk Plan Development Spare Part Equipment Plan Development			Maintenance Strategy Updates Resource Plan Updates Spare Part Procurement and Preservation and Storage			Maintenance Strategy Finalization and Approval
2	Data and Information Acquisition	Definition of data and Information required			Acquisition of Detailed Maintenance Data Data Categorization and Assessment			Update Maintenance Database Assess data and re-categorize			
3	Maintenance Strategy control and monitoring	Define controls and monitoring of Maintenance strategy						Non-Conformance Management to update maintenance Strategy			
4	Record and Documentation Control	Record Plan Definition						Information Compilation and Record Verification			Maintenance Data and OEM Manual Handover As-Build Information Handover
5	Maintenance Cost Plan							Maintenance Cost Plan Development			

Table 4: Maintenance planning & readiness assessment class.

Item #	Item Description	AOR Support Planning and Implementation (Weigh 10%)								
		PROPOSED METHOD								
		Conceptual Phase			Definition Phase			Execution/ Implementation phase			Commissioning /Takeover Phase
1	AOR Manpower	AOR Team Establishment			AOR Team Training and Development AOR Team Roles and Responsibility Definition AOR Team Deployment						AOR and Commissioning Support
2	Project Resource Support	Software Support System Establishment AOR implementation Tools identification			Definition of Operational Support Plan			Operational Support Plan Implementation			
2	Quality Control and Assurance	Quality Support Requirement									

Table 5: AOR support readiness assessment class.

Item #	Item Description	Computerised Maintenance System preparation and Integration (Weigh 15 %)								
		PROPOSED METHOD								
		Conceptual Phase			Definition Phase			Execution/Implementation phase			Commissioning /Takeover Phase
1	Business Project Charter	Maintenance Requirement			Define Standard Operating Process Develop Implementation Plan					
2	Record and Documentation Control	Information Requirement Definition								
3	Maintenance System	CMMS Process Flow Development			Detail the Process Flow Activities			CMMS Process Finalization Initiate Data Input Configuration of System			Commission System
4	Resource Planning	Implementation Team Establishment			Establish the Training Requirement			Provide Continuous training to the System Users			
5	CMMS Monitoring and Control							Establish System Audit Requirements			Process and Data Audit

Table 6: CMMS readiness assessment class.

Item #	Item Description	Life Cycle Risk Control Readiness (Weigh 20%)								
		PROPOSED METHOD								
		Conceptual Phase			Definition Phase			Execution/Implementation phase			Commissioning /Takeover Phase
1	Business SHEQ Policy	SHEQ Contract Development EIA Study Project Due Diligence								
2	Risk Management	Establish Risk Assessment Method Development of Risk Register Establish SHE & Q Management System			Update Risk Register Risk Strategy Development Detail Acceptance Criteria Definition Performance Indicator Disaster Recovery Plan Permitting Requirement Definition			Update Risk Register Permit Issuing and Permit Control			Safety Clearance and Issue Compliance Certificate
3	Risk Manpower	Risk Team Establishment (Done)			Risk Team Training			SHEQ Awareness Training Provide Oversight			Provide Oversight on Commissioning Activities

Table 7: Life cycle risk readiness assessment class.

6.3. Quantitative Survey Questionnaire

The developed qualitative survey questionnaire has four categories related to the AOR theoretical framework, which comprises of general section that covers the Organizational objective, asset related questions that covers AOR strategy and capacity to fulfil AOR readiness roles in a drastically changing technological environment, and impact of the current employed AOR approach. The questionnaire has the potential to reveal the key aspects of AOR, which becomes input towards developing a comprehensive AOR framework.

6.4. Proposed AOR Framework Scoring Model

The AOR Class assessment tool shown on Table 3 to Table 7 have a number of PLCM phases as defined and outlined on Figure 2. The phases considered in the assessment tool are in line with the proposed AOR framework process flow detailed above. The assessment tool used on the case studies applications (CHAPTER 7: AOR FRAMEWORK APPLICATION) has been embedded with both the weigh for each class as well as the scoring for each component in order to derive the probability in percentage of success on specific case study conducted.

LEGEND	Component Level			Class Level		
	Description	Scoring		Status	Weight (%)	Coding
	Fully Compliant	3		Good	≥80%	
	Mostly Compliant	2		Need Improvement	50% - 80%	
	Partially Compliant	1		Poor	≤50	
	Not Implemented	0				

Table 8: AOR class assessment tool criteria definition

Table 8 shows a summary of the criteria used to perform the assessment on the case study. The summary shown consist of two section with the left hand side applicable component for each phase of the PLCM, while the right hand side applicable to consolidated rating for each class (i.e. AOR support readiness assessment).

Table 9 gives more details of each description shown on Table 8. The unique icons used to depict score ranging from number 0 to number 3 shown on Appendix B and Table 8 deals with the representative scoring for each phase. The scoring is for assessment purpose as well as quantification of performance. The icons or scores links to descriptions, which gives further details as shown on Table 9.

The weighing in percentage shown on Table 8 right hand side follows the same narrative used to rate results in the qualitative survey questionnaire. The categorization depicted in Table 10 aims at highlighting the areas, which require attention from the business perspective.

Criteria for rating key activities in life cycle each stage			
Rating Type	Score	Non Compliance type	Detail Description of Weighting
Non-compliance to requirement	0	Major Non-compliance or Not considered	None of the requirements are met and there are no controls in place to rectify the non-compliance. There is no documentation to prove any compliance to the requirement. Violation of the set standard of providing service.
Partly compliant to the requirement	1	Minor Non-compliance	The criteria have been implemented at a later stage and needs to be monitored due to its impact on the AOR. The implementation meets the requirement partly and there are concessions granted to operate the asset. There is missing documentation for the asset which cannot be generated to meet the minimum requirements There are poor controls which allows the system to be operated without accountability and also deem the asset non-compliant.
Compliant to minimum requirement	2	Acceptable	The minimum requirement set are met with the minimum documentation in place as proof of the works being done The risk to impact on the AOR is minimum with low monitoring measures required.
Fully Compliant to all requirement	3	Well-Executed	In this area the activity must be implemented fully in a systematic manner while ensuring that each activity is executed in the right phase of the project as per the best practice proposal framework. There must be documentation which supports the claim that work was executed fully.

Table 9: Details of an AOR assessment tool stage wise scoring criteria details.

6.5. Proposed Quantitative Survey Questionnaire Scoring Model

Table 10 provides the qualitative survey scoring criteria used to derive the result shown of Table 15. Table 15 depicts percentage calculation from using the equation shown on Table 10 which gives provision for elimination of items not applicable to a candidate interviewed.

Qualitative Survey Scoring Criteria			
Survey Option	Scales	Result Confirmed (μ)	No Confirmation
Yes	1	N/A	N/A
No	0	N/A	N/A
Partially Fulfilled	0.5	N/A	N/A
Not Applicable	0	-1	0
Category Percentage Calculator=	$\frac{Sum\ of\ Category\ Scores}{maximum\ item\ count + sum\ of\ \mu\ Result\ Confirmatio}$		

Table 10: Quality survey categorization for interviews conducted in percentile

Table 11 shows a proposed categorization of the results for case study qualitative survey questionnaire. The three percentile relates to the magnitude of challenges ranging from; poorly executed, need for improvement, and acceptable with minor improvements, and the respective challenges are reflected by percentile of below 50, between 50 and 80, and above 80.

INTERVIEWEE RESULT CATEGORIZATION				
	GENERAL	EQUIPMENT & DATA	COMPETENCY	POSITIVE IMPACT
Percentile ≥ 80				
50 < Percentile ≥ 80				
Percentile ≤ 50				

Table 11: Proposed survey categorization for interviews conducted in percentile.

7. AOR THEORETICAL FRAMEWORK APPLICATION

The section on AOR framework application covers four areas used to carry out case study on a real-life project. The areas include; AOR framework case study, RCA application, Qualitative survey questionnaire application, and project Information assessment. The AOR framework application uses one of the mega New Build Power Plant project in Africa as means of validating the AOR framework, as well as identifying the areas of improvement in capital projects holistically.

7.1. AOR Framework Case Study

AOR case study section covers mainly areas in the new build boiler Power Plant, as it is one of the major and critical parts of the overall Asset. The selection of the case studies areas takes into account the significance of the Power Plant package and has been limited by the available time to carry out the investigation. The limitation aforementioned does not affect negatively the strength of the validation process to ascertain the contribution of an AOR framework. The cases studies discussed below include auxiliary boiler system effectiveness, coal mill effectiveness, Pulse Jet Fabric Filter (PJFF) effectiveness, and steam generator effectiveness.

7.1.1. Case Study: Auxiliary Boiler System Effectiveness

The organization uses a steam generation system, which its purpose is to supply all the boiler plant units (unit 1 to unit 6) with the required steam at multiple points of the plants for startup and commissioning activities. This is the first Power Plant, which has a permanent auxiliary steam generating plant used in the Operations and Maintenance (O&M) phase of PLCM.

The auxiliary boiler system will be used to effectively startup any of the six units in case of multiple trips and station blackout during O&M phase. The design of the auxiliary boiler Plant has three auxiliary condor boilers, which can produce steam at a rate of 28 kg/s.

The auxiliary plant supplies steam to various points of the plant which includes the boiler warm-up, boiler steam air heater, PJFF, boiler and gas air heater steam soot-blower, boiler firing system, boiler mill inerting system, auxiliary boiler, boiler hot-

standby, and some of the areas of the turbine such as turbine feed-water heater, and so on.

In the construction phase of the project, there were challenges, which emanated, and resulted in a number of technical dispositions from the non-conformance report issued to the appointed main contractor. The following highlights the challenges identified on the auxiliary boiler section:

Construction Challenges:

- High number of failures on the core air fan bearings on all three Auxiliary boiler Systems. This was mainly due to the OEM maintenance routines not been followed by the main contractor in the maintenance of the bearings. The dirt accumulation on the bearing shows evidence that the recommendations outlined on the OEM Maintenance manual were not implemented as required and there was no adequate oversight to ensure that such an event does not occur.
- Abnormally high number of feed-water perforated cone spindle failure. The resolution to aid with mitigation of the failure was to close the value completely which will isolate the steam flow and prevent high stress which causes bending on the spindle. The modifications on the spindle was part of the options to improve the condition during operation, and the documentations for the modification are not necessary as that forms part of the recommendations listed on the original documentation
- The allen cap bolts coming loose on butterfly valves and some were missing. The loose bolts have been due to lack of tightening and fixing. This results in lack of quality control during the construction process. This has resulted to new bolts provided and implementation of tack welding to ensure that the bolts permanently in position as per the OEM procedure.
- The high number of burner electronic cards failures experienced on the auxiliary boiler plant. The failure arise from unstable electrical system and the electric system were stabilized and a reduced number of failures due to interventions by the main contractor to Operations and Maintenance (O&M) as per the OEM recommendations.

Design and Stakeholder Relationship Challenges:

The major challenge which the auxiliary boiler has experiences is the deviations to regulation requirements. The auxiliary boiler has been designed and manufactured before the Department of Environmental Affairs (DEA) amendments on the standard, and the amendment have called for stringent emission regulations which the auxiliary boiler design are not meeting.

The standard 35883, draft declaration of small boilers as controlled emitters which regulates the emissions of small boiler, such as the Organization's auxiliary boiler, has shown that the current auxiliary boiler exceed the set emissions of sulfur dioxide (SO_2). the auxiliary boiler SO_2 limits violate or are non-compliant with the National Environmental Management Act (NEMA) and this poses a risk on the environment as well as on the financials of the Organization.

The auxiliary boiler will require a concession from the DEA in order to operate in future. Rejection of this option by the DEA standards then the auxiliary boiler entails no operation, which means make the capital expenditure a waste.

The AOR framework proposed has a role during the modification to ensure that all necessary steps which are required are done correctly so that the issues of code oversights and lack of consultation with the key stakeholders such as DEA or any other body is avoided in the process. The modification, if any, will include concept, detail design, construction, and handover activities to deliver the product to the client.

The assessment on Appendix A shows that there were issues with a list of items from different stages of the project. This has contributed to the challenges faced by the project although most of the issues were resolved prior to handover.

Mitigation Options to eliminate Design and Stakeholder Challenges:

The failure to secure a concession from the DEA will result in more cost to the project. The secondary options are to modify the various plants integrated to the Auxiliary boiler to be able to provide steam during startups and total blackouts. The option to consider are as follows but not limited to:

- To leave the auxiliary boiler setup as is with the current excessive SO2 emissions. This option will lead to penalties and ultimately revoking of permit to operate the auxiliary boiler plant. This has environmental impact as well as financial impact on the Organization.

- The second option was to request extension to implement a solution, which can aid to reduce the emission and meet the SO2 limit set by the regulator. This extension is in line with the date granted initially for the organization to comply with the limits.

- The third option is to integrate the auxiliary boiler to the Flue Gas Desulphurization (FGD) system. Taking this option will mean that the SO2 emission from the auxiliary boiler will be rerouted to the FGD which will reduce the SOx on the auxiliary boiler. This option will take time to implement, as there is a need to follow the LC project model to deliver the final product. There is a financial implication for this option that needs consideration by the Organization's investment forums.

- The other considered option as a mitigation measure is to introduce additives to the fuel oil supplied to the auxiliary boiler system. The idea is to reduce the emissions and improve the combustion while reducing the blockage in the burner lances. The flue system process allows for injection or addition of the additives at several points, and this will take some time to implement.

  The constraint on time will require additives injection to the bulk fuel oil tank, which only requires a minor modification, which reduces period.

- This option will consider change in fuel oil supplied from heavy to lighter fuel oil. This will entail that the modifications included storage tanks, lines or piping and pumps, and any other necessary adjustment to ensure compliance to the regulations.

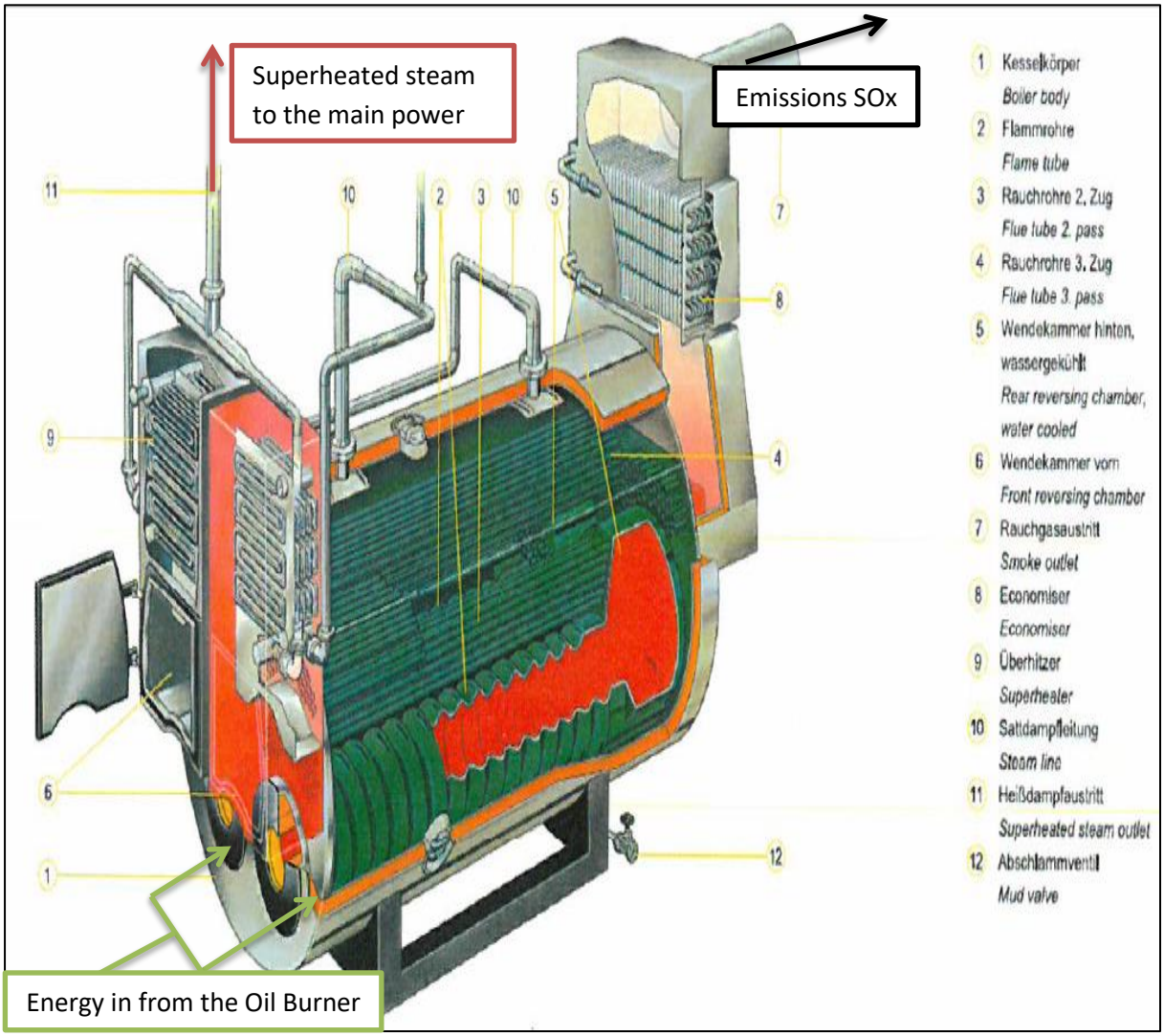

Figure 35: Auxiliary boiler plant (without an oil burner) overview schematic (Sobbe, 2013).

- Other options are to either reduce Sulphur content in the fuel oil or modify the unit burner atomizing system design to compressed air. The modification of the unit burners entails that the new arrangement will be to utilization of compressed air instead of steam as an atomizing medium. There are advantages and disadvantages to factor in the conceptual and detailed design phase if the organization decides to go with this option.

- The last option was to operate the auxiliary boiler at the reduced MCR based on the linear SO_2 curve. The reduced MCR will reduce the SO_2 emissions and aid with the compliance to the regulators limits. This option might appear to be the most feasible and the most convenient to implement but there are lot of

unknowns as the contractor information on these boiler is not sufficient to conduct an engineering assessment.

The steam quality will be the main element to consider if the boiler operates at a lower MCR. Other impact of this option is longer startup time for the units, which lead to cost and delayed production.

The auxiliary boiler schematic on Figure 35 show the fuel into the system to generate the energy required for steam production. The steam produced in this Auxiliary boiler aids in the main boiler for the purpose of total blackout start-up and commissioning activities. The absence of this system will induce challenges to the Organization in terms of cost, production, Power Plant start-up.

7.1.2. Case Study: Coal Mill Effectiveness

The Organization has experienced a number of challenges, which emanate from failure in some of the processes to ensure AOR effectiveness. Figure 36 and Figure 37 depicts boiler coal mill plant selected during the tendering process. The two Figures show the sections of the Coal Mill Plant with all the components. The RCA discussed in Chapter 7.2.2 gives an overview of the issues pertaining to the coal mill from all three AOR dimensions which include human, physical, and process.

The issues identified and outlined on the RCA section relates to lack of well-structured AOR framework, required to assess the level of challenges through a rating process in each stage of the PLCM.

The coal supply has been one of the major contributors to the ineffectiveness of the coal mill plant. This item reveals the gap in the contracting phase of the project for specific type of coal and control measures failures, which were necessary to ensure project receives quality product.

The issues experienced with the coal have led to some of the challenges faced during operation of the plant. The issues that emerge include the damage identified with the rotating nozzle rings, which show high rates of erosions. The failure to ensure that all the element of the power is ready for operation has an impact on the

reliability and availability of the plant due to unplanned outages and this has an impact on the maintenance philosophy employed.

The coal quality was in question during operation with large amount of foreign objects removed from the mill rejection box shown on Figure 37. The evidence relating to poor coal quality emanates from the assessment of the wear rate comparison of two periods of operation. The previous mills were able to last longer as compared to the current mills affected by the coal quality.

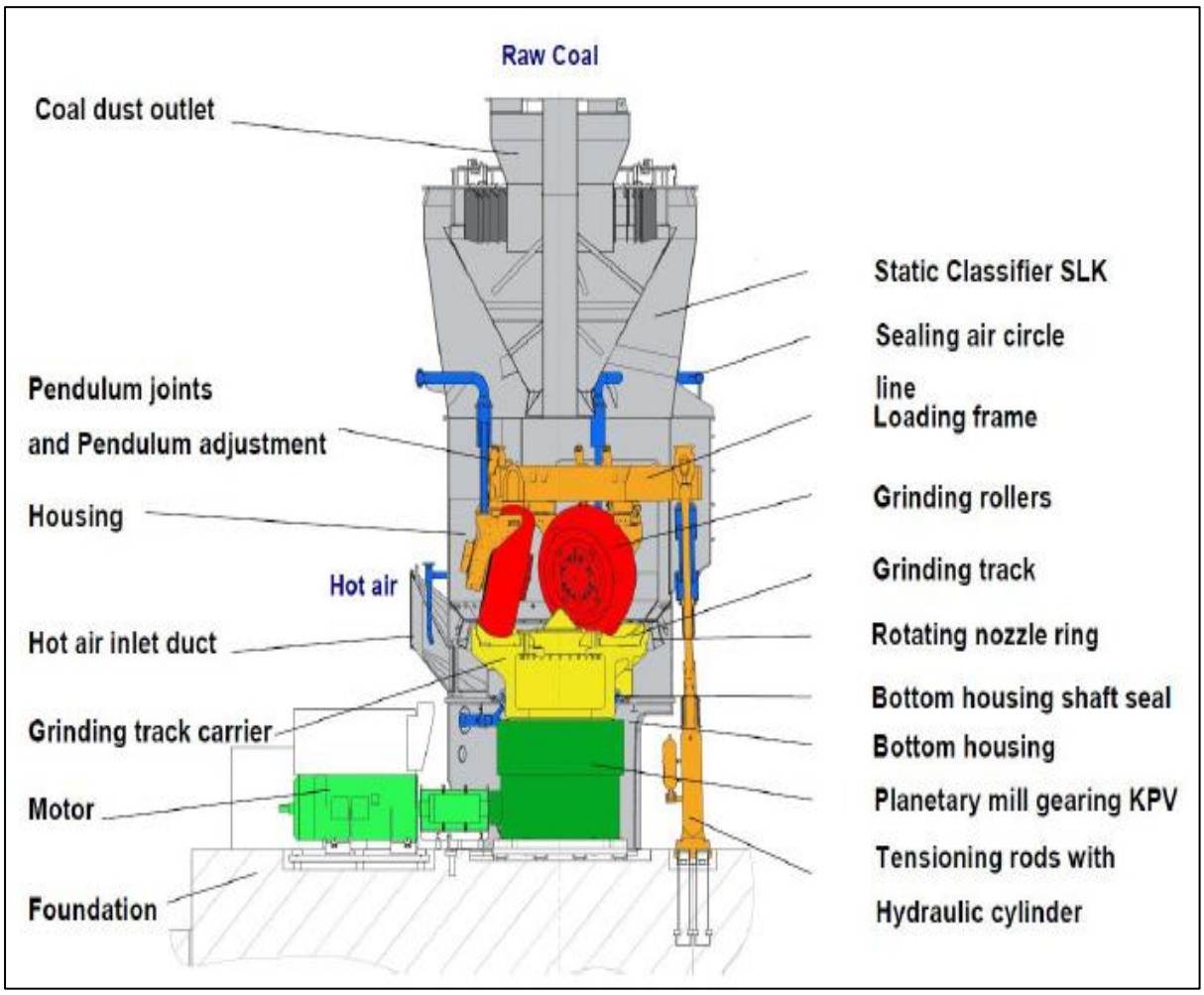

Figure 36: Schematic of the MPS coal mill showing all the components (Koko, et al., 2009).

The details review during the early stages of the project with the correct skill-set is one of the elements, which requires close assessment as this is the main cause of some of the technology selections. There is expectation of foreign objects in an operation of this magnitude and relate to various factors such as sabotage, or carry

over of foreign objects, and this is one of the major design consideration for mills and the supply chain of the coal. The plant has a mill reject system, which caters for removal of overweight foreign objects.

The AOR framework assessment as a tool, which has incorporated raking for each phase of the projects to ensure that the plant is ready for operation, could have been used to flag that the key elements of AOR in definition phase are not in a 100 percent state. Flagging the delays in AOR planning and implementation strategy could have assisted in a drive to assess all the other components in details to avoid low scores on the subsequent assessment phases.

The assessment conducted on the coal mill plant operation shows that the operating philosophy implementation was as per the OEM's recommendation. It was clear that the operation issues do not relate to the failure in components in coal mill. The grinding rollers have been one of the components, which had frequent replacement from excessive wear rates due to the coal issues.

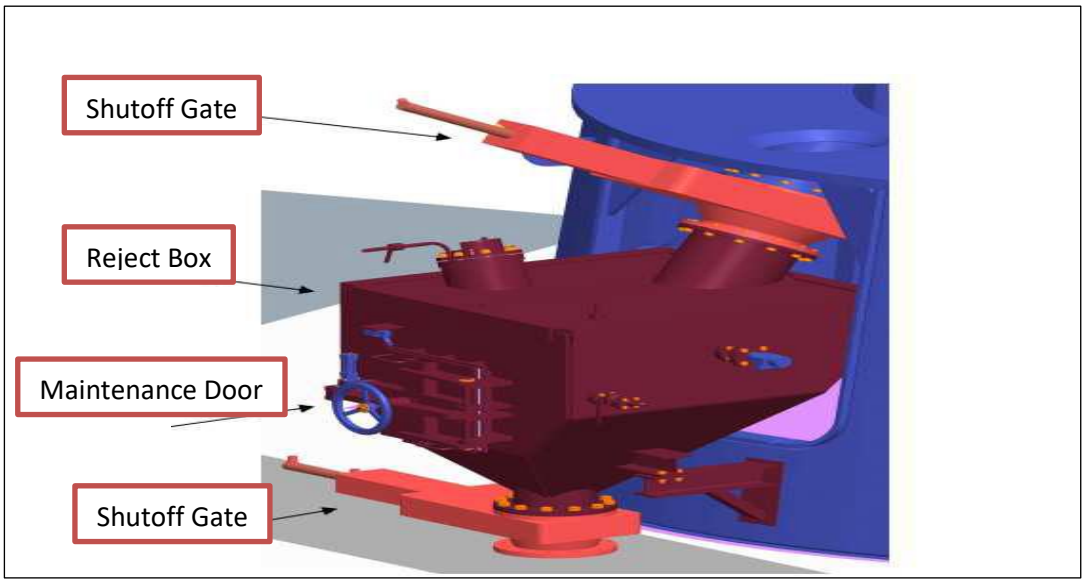

Figure 37: Schematic of the MPS coal mill reject system.

The detailed assessment of the failure could have been verified internally with advanced design tools to ascertain the spare part requirements in normal and worse case scenarios. Chapter 8 gives a holistic view on the issues, which contributed to some of the challenges faced with the equipment discussed in this section. The

design review procedure, which incorporates AOR function, appears to have played a critical role in verification process in all the stages.

7.1.3. Case Study: Pulse Jet Fabric Filter Effectiveness

The Pulse Jet Fabric Filter (PJFF) operation is as per recommendation by the OEM and there are defects identified and outlined in section 7.2.3 through a RCA to ascertain some of the control failures in the PJFF PLCM. The required corrections implementation has taken place for some of the defects identified as part of the contractual agreement.

The PJFF have not performed as per the contractual agreement although some of the defects are closed. The issues, which identified during commissioning and commercialization of the PJFF, include flow irregularities, emission excursions, and pressure differential issues amongst other issues.

The issues aforementioned have repercussions discussed in Chapter 7.2.3 and documented in Appendix A. The issues which have been discussed under the RCA section take into account the three dimensions (human, physical, and process) as mentioned above, and show the failures in the controls thereof.

The key elements which resulted in the failure of various systems (manufacturing, quality, design validation) in the life cycle of the PJFF is the contractual deviation to bag life duration which is expected at 36000 hours, pressure deviating from the required 2.5 kPa, emission limited to 50 mg/Sm^3, and reduced bag cage lifespan.

The ultimate issues aforementioned are evidence of lack of understanding of the design review details, which should take place during the definition phase and this relates to the failure in implementation of the design review procedure to ascertain the state of AOR at an early stage of the project. The AOR design assessment tools made available by the project process team have not been sufficient for the mega capital project, and it is evident that in futuristic projects the AOR support is one of the key areas to consider as a major contributor to the project failure.

The ability of the organization to be able to appreciate the need for specialized design tool will ensure that future project are executed in a good manner and allows

for elimination of unnecessary operational issues post commissioning which will increase the maintenance costs.

The risks not identified during the early stages of the project due to lack of updates of the risk register as detailed in the discussion in Chapter 8.1.3 could have been avoided by deploying the AOR framework risk strategies. The deployment of such a strategy is required during the definition phase, which could have flagged that the risk in the commissioning phase might be high if the early phase validation is not detailed.

The risks which have been identified includes high emission, Unplanned Capacity Loss Factor (UCLF), and plant failure, and these have major cost implication from maintenance as well as productivity and profitability of the asset during operation. The indication of the risk is one of the major highlight, which compels the design team and AOR team to do a thorough assessment of the processes in the early stage in futuristic project to ensure reduced risk profiles.

7.1.4. Case Study: Steam Generator Effectiveness

The issues identified on the main boiler equipment has revealed failure in several aspects of the AOR components particularly on the AOR implementation and planning. The failures which are evident relates to the implementation of the Project Quality Manual (PQM) used for manufacturing activities, Construction Quality Manual (CQM), AOR strategy (Design Review Procedure), and AOR Support particularly of verification and validation tools. This is also evident on the RCA in section 7.2.4 which details the three dimensions and Appendices A4 and A5 preventive control failure.

The issues on the boiler furnace includes the misalignment re-heater (RH) bundle tubes identified during construction phase, Copper Contamination on the evaporator section, which results from manufacturing oversight, poor absorption of the boiler furnace on re-heater section, and RH Spray flow defect, which has a major role in the risk associated with the AOR of the Power Plant.

The deviations identified are issues, which show the importance of the AOR components in every phase of the project. This shows that the compliance issues

have been experienced in all the phases of the project, which entails that, the maintainability, reliability, and availabilityof the plant is at risk. Addressing the issues has high cost implications and one of the options is to de-rate the Power Plant ultimately reducing the Return on Investment (ROI) of the project in the projected period.

7.2. Root Cause Analysis Study

The Root Cause Analysis (RCA) proposed model on Figure 33 assists as an improvement tool towards case studies assessed using the AOR theoretical framework. The RCA application appears on Appendix A1 to Appendix A5 of the research study. This section covers assessment of four cases using the integrated multi-technique RCA approach proposed model. The assessment considers coal mill, auxiliary boiler, PJFF Design, and Boiler Furnace (main steam generator).

There are processes and controls established for the equipment assessed below and those processes cover the Design Freezing at the end of design phase, Integrated Design Reviews (IDR), and Quality Control (QC). The expansion of aforementioned as outlined below provides clarity on the list of items included in the verification processes.

The design review performed was mainly to verify the design and layout drawings, functionality and process, interfaces with other systems, engineering related changes and applicable material, equipment, HAZOP study, RAM analysis, and spare part requirements. This end-of phase design freeze elements reviews have been carried out in all the cases mentioned in this section with oversight to some on of the element due to lack of information thereof.

The Integrated Design Review (IDR) stage used by the engineering team is one of the verification points to check if the product in question compliance provides certain level of assurance. The stage covers verification of User Requirement Specification URS, compliance to codes and standards, meets the minimum equipment or system testing requirements, constructability using tools such as Computer Aided Design (CAD), Operability and Maintainability (O&M) of the equipment, interfaces, and compliance to RAM and other environmental and safety requirements. The Project

Quality Manual (PQM) gives an overview of the quality processes to ensure delivery of a quality product after manufacturing and construction activities.

The review is limited to the list of documents submitted by the appointed service provider or contractor and agreed upon on the URS. The URS has been one of the project flaws, as it does not explicitly details the service provider scope to avoid ambiguity between interfacing packages.

The controls listed above have three sections which needs to be taken into consideration and those sections includes the human factor, the defined process, and the product delivered in order to guarantee a quality end-product which are discuss below:

- The lack of specialised personnel to perform the review at the initial stages of the PLCM has led to oversights, which are consequential to the failures identified in the RCAs below.

- The process development, which happened over the years after initiation of the New Build Projects, has addressed some of the design, interface, and constructability of the Boiler Plants. The lack of integrated and robust process in the first stages of the New Build Project has led to identifiable gaps in the implementation phase of the projects. The establishment of process control manuals through Organizational initiation to have well-defined governance and standardized processes addressed some of the AOR elements. The AOR team remains function, which does not operate independently to ensure quality product delivery without any interference.

- The physical product goes through a quality control process detailed in the PQM, and other agreements made during the kick-off meetings relating to manufacturing or construction proceedings. The magnitude of a project and the type of contract determines the level of involvement on the project activities. There have been poor communication by the contractor or service provider to ensure that the client is involved in every intervention point before release of

component as this is evident on the final documentation provided by the service provider.

Some of the physical components release or acceptance by the client is not in line with the correct processes detailed on the PQM or agreed upon by all parties. Both of the aforementioned cases have led to the client design engineers and client project management having to consider technical positions from the service provider to accept the plant outside of the agreed processes and codes and standards.

The points outlined above have a major impact on the performance of the asset as this has the potential to compromise the design and quality of the product technically. The section below gives a more specific outline of the issues identified on the four cases assessed using the RCA model.

7.2.1. Auxiliary Boiler Emission RCA

The Auxiliary boiler is one of the essential systems used during commissioning and start-up of the main boiler plant. The purpose of this plant is to generate and supply steam to the boiler for the activities aforementioned at the desired parameters. There are three small auxiliary boilers constructed for the aforementioned purpose as a permanent part of the Power Plant as opposed to other fleet. The design of this nature emanates from the design phase with compliance to the regulatory requirements as set by the governing body (DEA). The three areas of RCA assessment below to give an overview of the gaps, which led to the current non-compliance:

Human element

- The human related gap identified in this regard, emanate from the lack of continuous engagement with the necessary forums, which review and revise the standards governing the small boilers. The failure to have a well-defined communication matrix (RACI) in the Project Charter that integrates with all the necessary stakeholder visions and objectives has led to oversight during the procurement and registration of the small boilers.

The leadership which is supposed to drive the implementation of the communication procedure are required to ensure that any project decision which are impacted by the environmental regulatory changes are continuously attended to in order to avoid instances whereby the regulatory bodies are making changes which deems the equipment not technologically ready to operate at the desired parameters.

Process element

- The process challenges identified in the RCA assessment have shown that there is a gap on development of the processes to ensure compliance as such major investments cannot have a simplified solution to reduce the emissions levels to required parameters. The gaps identified are on stakeholder involvement and communication, which could have mitigated the current challenges faced by the Organization.

  Informing the Forum that revises the Air Quality Act, about the conditions of operation of the small boilers was vital as part of stakeholder engagement. This entails that during development of the standard, a concession could have been issues to the organization to operate outside the required parameter, as there has not been any budget allocated to the modification of the small boilers.

Physical element

- The revised version of the air quality act introduced new set limit for the emissions acceptable on the small boilers which meant that any excess emissions from the small plant will results in penalties or complete shut-down of small boiler plants. The standard published (Regulation No. 35883) for small boilers as means of regulating and capping the emissions to the environment has led to the constructed boilers not meeting the required set limit.

  The governing body has called for the organization to intervene in addressing the excessive emissions measured during the operation of the small boilers in order to retain the permission to continue operating the small plant. This has led to

other risks not catered for during the design phase of the PLCM of having a Plant not ready to operate in an event of blackout. The secondary risk relates to additional cost incurrence due to failures in the system to assess the readiness of the technology before procurement.

7.2.2. Coal Mill Effectiveness RCA

The new build coal mill has been one of the equipment, which has seen major damages during its operation, and it was necessary to assess the causes of the damage, as this is one of the important equipment for generation of steam in the boiler furnace. The coal mill follows the design phase end of life review and integrated design review processes, which caters for all aspect of the vertical coal mills. The mills have seen major deterioration or damages, which links to design deficiencies, coal composition and size issues, and foreign material that end up in the mills.

The RCA on Appendix A2 gives a stepwise causality analysis of the issues pertaining to the vertical mills used in the new build boiler plants. The RCA performed reveals that there are issues or events from each category (human, physical, and process) which contributed to the ineffectiveness of the coal vertical mills. The categories assessed in Appendix A3, are as follows:

Human element

- The human element has contributed in numerous ways are shown on Appendix B and that related to the oversight on the design verification in the initial stage of the project (design/engineering phase) which meant that some of the issues relating to the final product were not identified and eliminated at that point. The event, which might be more related to the quality of the mill as oppose to the inception of the coal into the mill, is the quality process oversight during manufacturing. This has consequences on providing assurance to the client that some of the failures are merely operation failures rather that defect not identified throughout the supply chain.

Preservation and inspection on site might have been another gap, which requires process review to ascertain the contribution of the human errors and incompetency to perform a task as per the governance or quality processes.

Process element

- The process failure of this specific RCA shown on Appendix A3 is due to lack of well-defined standardized processes development to address issues at the initial stages of the project in order to avoid oversight of important elements such as design gaps. The failure in processes has a bearing on the lack of risk assessment and risk mitigation strategies and this is evident with the final product under operation.

Physical element

- The failure to integrate the client IDR, OEM design limitations, and coal procurement contract has led to major challenges in terms of ensuring that the right quality coal enters the coal mills. The continuous issues with the coal are due to the lack of quality control measures to analysis the coal quality and filter out the foreign materials and stones. The coal mills rejected foreign material and oversized coal are evidence of failure in the supply chain foreign object filtration system and this is one of the items which should have been considered in the design review phases as it has been on the crashed coal (PF) transported to the boiler furnace for boiler fires.

  Other related design deficiencies is wearing of mill internal components due to stones, iron material, as well as seal air issues, which cause erosion on the internal.

7.2.3. Pulse Jet Fabric Filter Effectiveness RCA

The Pulse Jet Fabric Filter Effectiveness (PJFF) as a system, which plays an essential role in cleaning (removal) of the by-product (particularly Fly Ash) from the burnt PF in the furnace, requires operation at optimal point to avoid excess emission to the environment. This system and other similar technology have become one of

the most crucial in energy production due to the pollution, which comes with the types of fuel used to generate steam in a boiler plant.

There have been challenges on this technology are those issues identified relates to the design, human intervention, and process are captured in Appendix A3 PJFF RCA. The RCA assessment covers similar categories as indicated on the previous RCA, which is as follows:

Human element

- The human element issues covered in this category include the design deficiency and oversight thereof as detailed on the previous RCA discussion, the quality control oversight on manufacturing and construction site. The quality oversight or quality process failure links to continuous monitoring of the filtration bags during manufacturing, shipping and handling, and installation on site. The damages on the bags are one of the evidence of handling and installation issues as well as quality control oversight. This type of oversight can be due to lack of knowledge and skill from people responsible for manufacturing and construction or pure incompetence to detect the damages before plant use.

Process element

- The process challenges as discussed on the previous RCA relates to the lack of standardization and well-defined process control manual for the project of this magnitude. The failure of design processes, AOR process and detail design review have led to oversight on identification of risk associated with the level of verification and validation at the initial stage of the project. The risk identification would have had a positive impact on the overall design due to the opportunities, which arise of developing a risk mitigation strategy.

Physical element

- The physical failure identified on the RCA also related to the design deficiency with the flow pattern irregularities and flow error correction mechanisms not adequate. The design does not have adequate measure to regulate the temperature from the boiler furnace to the PJFF and this has severe implication on the system due to the PJFF Bag accelerated degradation and fly ash erosion.

The flow pattern also contributes to the fly ash erosion as well as other failure modes such as Bag Blinding, which emanates from uncontrollable high from Flue Gas (FG), moisture in the FG to PJFF, Fuel Oil carry-during start-up, and out-of-specification ash composition.

7.2.4. Steam Generator Effectiveness RCA

The Steam Generation Effectiveness (SGE) RCA covers four identified issues, which includes copper contamination in the evaporator section, Thermal expansion of boiler furnace bundles, RH Spray flow, and heat absorption of evaporator. The aforementioned issues assessed using the integrated RCA model as means of ensures that there is thorough assessment of the causalities that have led to these particular primary events.

The SGE RCA similar to the other results discussed above takes a glance at three areas which are namely; human related events, process related events, and physical/equipment related events, and these events are discussed in detailed below in a more integrated manner as some of the event are of the same magnitude and also common:

Human element

- The human aspect of the four assessed SGE cases relates to couple of items not necessarily related although some are also highly probably events for due to the nature of the project and activities thereof. The human factor, which played a crucial role in all the cases, related to design reviews and quality control/assurance. There is oversight relating to lack of competencies or skill in the initial stages of the PLCM, and lack of stakeholder identification to perform certain tasks, in order to ensure all the controls are refined to mitigate major gaps in the implementation phase. The aforementioned human related issues are across the board and appear on Appendix A4 and Appendix A5, which represents all four cases of the SGE.

Process element

- The process related challenges are also issues due lack of integrated system/process as per international best practice to enable the organization to carry projects at this magnitude. There are process considerations not catered for such as having an independent team to verify all project readiness steps to the required details in order to mitigate all possible risk associated works execution. The readiness team was to comprise of specialized skills in all areas on the project ensure that the processes underway are carried out as per agreed integrated readiness framework.

Physical element

The events experienced by the project depict an induced string of sequential events due to few or single identified event or challenge.

- The identification of thermal expansion issue was on the early stages of the project when inspecting one of the New Build unit pressure parts section. The non-conformance was primarily to highlight the deficiencies relating to the tolerance or clearances between the boiler furnace walls and the suspended boiler tubes bundles.

  The OEM intervene to correct the non-conformance by trying to optimize the position of the bundles in order to achieve the necessary clearance, and in that process there was oversight on the clearance between the suspended bundles and one of the walls which led to some of the bundle element being misaligned to unfavourable positions. Design calculation were carried out and anan agreement was made to allowed the OEM to proceed with the construction works, and later it was identified that the boiler vertical wall width are not as per the design which meant that the absorption surface has been tempered with.

- The copper contamination event is one of the issues, which shows the oversight on manufacturing stage of the project. This links to list of issues such as lack of competency to evaluate if an organization is ready to manufacture the equipment.

There are controls from the manufacturing entity as well as from the client to ensure quality of the final product. The oversight on these particular components shows the lack of understanding of the ultimate consequences of this contamination as well as lack of applicable manufacturing platforms to carry out this activity.

This relates to oversight on the engineering phase of the project to coin measures, which can reduce the risks of client accepting equipment, which is not at the desirable quality due to either lack of tools to verify or well-defined systems/process (preventive controls included). The welding machine guide rails used distributed the copper to the membrane walls fins and there were scratches identified. This type of contamination caused copper embrittlement, which led to cracks on the fins. The identified areas were grinded and repaired, although this as an event poses a risk on the physical equipment as well as individuals near the consequential failure.

7.3. Qualitative Survey Questionnaire Application

The need to enhance the knowledge on this study and on the subject has resulted in development of a survey questionnaire as well as carrying out the survey. The surveys carried out aimed at covering a range of roles within the project environment, and that includes interviewing project management, project practitioners, design team, as well as the user of the final product. The surveys turnaround was 75% in terms of role, which were accessible for acquiring information to enhance the AOR framework.

Although, this is the case, the project team has had a major role in ensuring that the plant handed-over operates optimally, thus assuming some of the functions of the end-user. Therefore, the data collected provides confidence for purpose of enhancing the AOR framework since it covers a significant footprint for the Capital Project in the discussion section.

The application of the qualitative survey questionnaire carried out using the detailed shown on Table 12 has questions categorized into 4 section namely; general aspect,

physical equipment and availability of data for O&M, competency readiness, other which represents the impact of AOR in an Organization.

INTERVIEWEE SURVEY						
			Interviewee Answers			
Item Number	Type	Questions	Short Answer (Yes/No)	Comments	Suggestion (Improvement)	Score
	GENERAL					
1		Is Asset Operational Readiness (AOR) plan or strategy (If any) well defined in the orgnanization?				
2		Is AOR a separate department with all necessary process and procedure?				
3		AOR budget clearly defined by the business for pre-feasibility phase to handover phase (PLCM)?				
1	EQUIPMENT AND DOCUMENTATION READINESS	Are all the Regulatory and compliance requirements for all the newbuild systems and equipment fulfilled?				
2		Are the systems/equipment delivered in line with the operational requirements?				
3		Is the Engineering and Quality Process implemented accordingly to Achieve system clearance and Registration?				
4		Has the business ensured that spare equipment, or maintenance and operational services required during operation are factored into the Life cycle model?				
5		Is the O&M documentation made available during commissioning or operation of the asset?				
6		Is the Electrical and C&I infrastructure/design adequately integrated to the mechanical equipment prior to commercialization of the asset?				
7		Is there a defined process for equipment re-location (swap) during construction?				
8		Is the Specification (Employer's Contract) adequately detail to eliminate ambiguity?				
9		Is the Intergrated Design Review Report sufficient for ensuring harmony between various stakeholder or interface?				
10		Is the Pre-Commissioning Review Report "details" adequate for readiness of the equipment to be commissioned in a safe manner?				
11		Is the Handover Design Review Report (Matrix) a good tool to verify the readiness of the plant for the client to operate?				
12		Is the Engineering Change Process, Risk Assessment, and Non-conformance Management well documented throughout the PLCM?				
13		Are all the Design Documents submitted on time with As-Build Information for Operation and Maintenance (O&M)?				
14		Does the project have detailed RAM (Reliability, Availability, Maintenability) Studies and is there a need to produce detailed RAMS for all the system?				
15		Bill of Materials documentation adequate to guide the O&M team on maintenability of the Power Plant?				
16		Is there sufficient Documentation for Procurement Spare Parts during Maintenance of the Plant				
17		Is the Spare Parts Documentation submitted prior to Operation				
1	COMPETENCY READINESS	Is the business aware of the importance of AOR to ensure that there are right skill-sets and competencies?				
2		Is there a programme to develop the staff identified for Plant Operation prior to Plant takeover?				
3		Does the business have a Methods to profile and assess the competency of each individual as they develop?				
4		Is the AOR team (if any) established at the right phase of the PLCM (Project Life Cycle Model) with well defined Roles and Responsibilities?				
5		Is there continuous improvement of individual skills to effectively outline and perform tasks and activities pertaining to AOR?				
1	OTHER	Is the AOR Process (If any) complimenting the delivery of the project?				
2		Is there an escalation process for AOR related concerns which has not been addressed during the PLCM (if AOR exist)?				

Table 12: Interviewee qualitative survey categorized into four sections.

7.4. Project Information and Data Management Assessment

The are several aspect of a project which lead to success and one of the major contributor to such is the data management which needs to be done according to the standards and contract structure agreed upon. The organization has decided to employ FIDIC contracting strategy as well as compliance to ISO standards for project delivery. Table 13 give substantial evidence on the documentation management in the project.

There is a document submission plan agreed upon by the project and it clearly shows that there is some detailed information, which was provided post awarding of the tender, or contract. The aforementioned entails that some of the detailed documentation were only available late in the project phase due to the approached used for contracting, and such planning reveals lack of understanding on the importance of thorough assessment or review of the equipment readiness. The lack of detailed information in the definition phase has confirmed on the qualitative surveys conducted and provided in Appendix C.

The Table 13 aims at verifying the documentation submitted as prescribed by the project milestone and partially highlighted on the agreed updated contract award submission. The submission of the information selected for verification shows that most of the detail documentation are submitted post definition phase of the project.

The late submission and delays, which the project experiences are also evident in the table and it has been highlight through the surveys that the contract has not included provision for penalization due to late document submission. This lack of implementation in the project is due to lack of detail in the documents used as agreements to hold parties accountable.

Item Category	Document Description	Submission months after Boiler Contract Award	Project Milestone (months)	Submission status
General	Detailed Contractor's programme	2	2	Achieved
Contract Review	Review and settle open specification/contract issues, (if any)		case by case	Partly achieved
Organisation Issues	Define and settle organisation framework		3	Partly achieved
Boiler	Boiler preliminary layout drawings	3	3	Partly achieved
Boiler	Fire risk analysis	2	15	Mostly Achieved
Mills,FD fans, ID fans, PA fans,	Final design calculations and detailed drawings of plant foundations	9	9	Partly achieved
Boiler	Initial general arrangement drawings		3	Partly achieved
Boiler	Preliminary interface list		2	Partly achieved
Boiler	Mechanical drawings showing design of the boiler plant and detailed components	42	42	Mostly Achieved
Boiler	Technical data of the pressure part including calculations and test certificates	42	42	Mostly Achieved
General	Quality documentation including QCP, welding procedure	1	1	Partly achieved
General	AIA mandatory monitoring schedule	2	6	Progressively
Boiler	Preliminary boiler material diagram	3	6	Partly achieved
Valve & fittings (including safety valves)	Design parameters.		6	Mostly Achieved
Lining & insulation	Design parameters.		24	Mostly Achieved
Boiler	Final boiler material diagram	42	42	Partly achieved
General	Manual including maintenance, commissioning	42	42	Partly achieved
General	List of equipment with all relevant data such as instrument lists, valve lists, insulation	42	42	Partly achieved
Legend:	Partly achieved	Mostly Achieved	Progressively	Achieved

Table 13: Tabulated technical information and data submitted compliance verification.

8. RESULTS AND DISCUSSION

This section of the report gives details of the assessment conducted using the AOR Assessment tool, which comprises of components extracted from the detailed AOR process flow framework proposal. The section covers four cases assessed using gap analysis in a form of consolidated multi-technique RCA, and proposes multi-disciplinary AOR framework.

The cases discussed include the auxiliary boiler plant, coal mill plant, Pulse Jet Fabric Filter (PJFF), and steam generator. The assessment further outlines the results from using of multi-disciplinary AOR framework assessment tool, obtained from the assessment of the entire mega capital project boiler plant. The assessment concluded using real data from the only local mega capital project in decade.

The discussion below gives insight on the state of the project and failures within the Project Life Cycle Management (PLCM). The challenges faced in the PLCM have high indirect and direct cost implication for all the defects and delays causes in the delivery of the project. There is confirmation by any personnel in the organization that there has been failure in delivery of New Build project at an optimized cost, as it is evident that the budget projected exceeds 50% of the original set value.

The cost excursion relates to several systematic and process failures but that does not exclude the boiler plant assessed. The cost overrun which have been experience also give evident of magnitude of the rework conducted and delays caused which ultimately results in claims against the client. The delays in delivering the project attributes but not limited to the lack of interface management amongst various stakeholders as well as contractual flaws to ensure the successful bidder is accountable.

8.1. Overall AOR Framework GACS Discussion

The assessment conducted with the information from one of the mega capital project gives insight on several elements to improve. This AOR assessment Framework is one of the rare assessment tools, which have various elements that aid in assessing a project in each stage to ascertain the readiness to operate, and this assessment applies to any projects ranging from small scale to mega scale. This section details the assessment conducted and outlines key point, which contributes to the performance as shown in Figure 38, Table 14, and Appendix B.

CASE STUDY ASSESSMENT RESULT SUMMARY						
Proposed Item Description and Weight	Conceptual Phase	Definition Phase	Execution/ Implementation phase	Commissioning /Takeover Phase	Final Score	Status
Maintenance Planning and Readiness (Weigh 20%)	87%	67%	67%	33%	13.33%	Need Improvement
Computerised Maintenance System preparation and Integration (Weigh 15 %)	83%	92%	80%	83%	12.67%	Good
Life Cycle Risk Control Readiness (Weigh 20%)	95%	90%	83%	67%	17.67%	Good
Operational Readiness Planning and Implementation (Weigh 35%)	83%	85%	76%	62%	26.79%	Need Improvement
AOR Support Planning and Implementation (Weigh 10%)	75%	83%	67%	67%	7.67%	Need Improvement
Boiler Plant Assessment Total Score =					78.1%	Intervention Required

Table 14: Result extracted from the boiler AOR assessment detailed on Appendix B.

Figure 38 gives a clear illustration of the results for each category. The legend on the graphical representation reflects PLCM phases sectioned for scoring each stage of the project. The graphical representation shows that there were more challenges

during the implementation and commissioning phase of the project when compared to the initial phases.

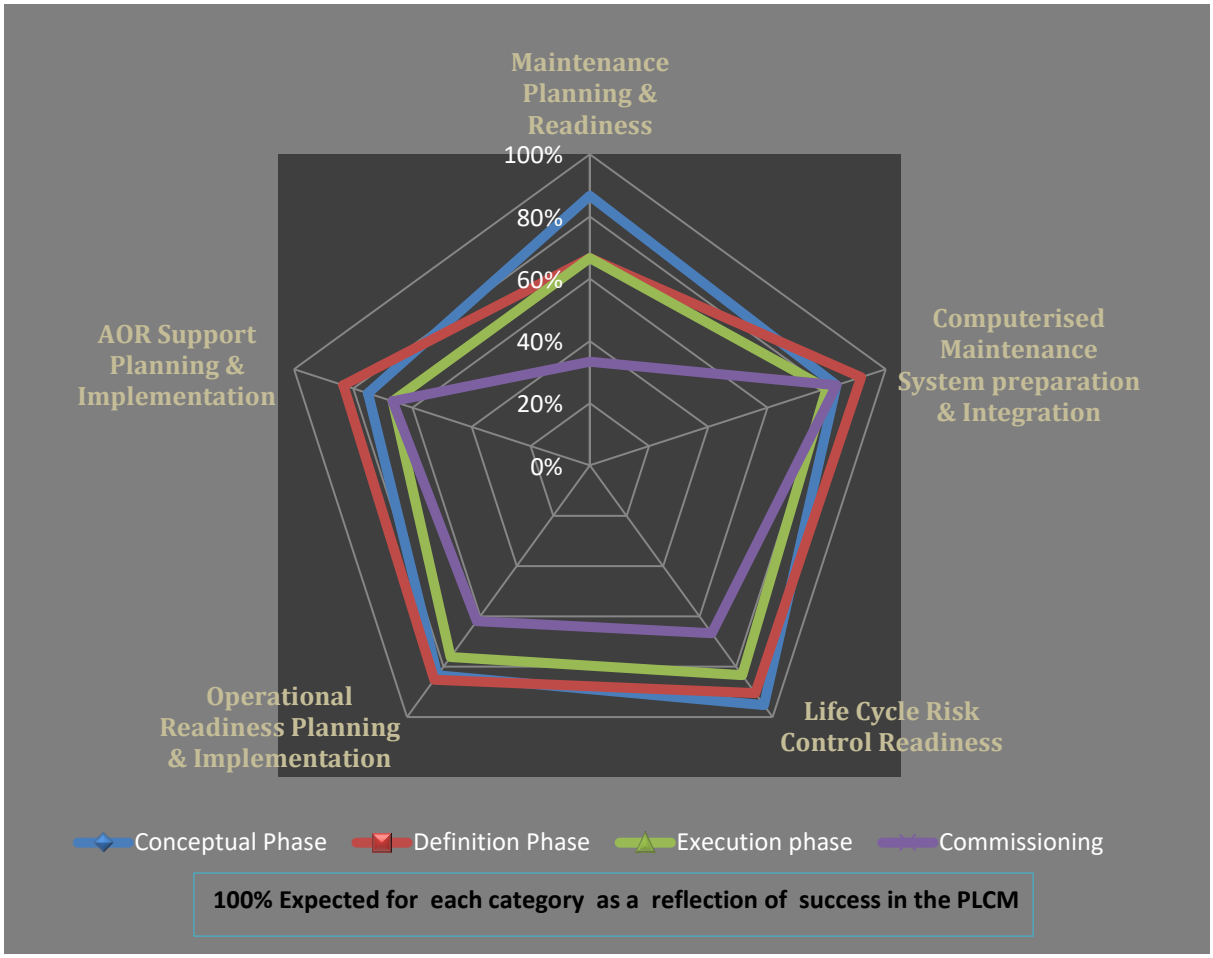

Figure 38: Graphical Representation of AOR case study assessment showing all the categories.

The maintenance shows a major lag in comparison to other categories and it is one of the key contributors to the overall performance of the project. The phase, which shows good sign although not necessarily meeting the expectation of 100% performance, is the conceptualization phase with an overall score above 80%. The conceptualization phase is one area, which does not require major intervention from the organization, and this entails that the organization needs to invest on the detailing phase as well as implementation and commissioning phases.

The results for assessment carried on each case has been consolidate below to give an overview of the new build boiler plant status in relation to best practice AOR

framework proposed. The section below covers in depth discussion on issues identified in the elements of AOR as shown on Figure 38.

8.1.1. Readiness of Maintenance during operation stage

The assessment shows that there challenges such as implementation of maintenance philosophy, has led to the project not realizing some of the milestones, which were planned in the early stages of the project. There are minimum requirement as per the proposed method, met with delays on the spare part plan and partial implementation of maintenance plan and costing associated. The failure to have a comprehensive maintenance philosophy on time has led to issues associated with procurement, as the client specification does not cover extensively the procurement of spare part for the purpose of maintenance and operation. Although the specification does mention maintainability of the plant, it remains a difficult to conclude on the details of spare part supply in most cases.

There are some decisions made, which did not factor the possibilities of late data/information submissions and this can be associated to lack of experience on mega projects and hindrances thereof.

Resource plan for maintenance of the asset is one of the component, which required major improvement should there be any future projects. This was factored partially with late involvement to the project, which led to issues with taking over the plan and also not sufficient period to understand the issues associated with the project before operation.

The assessment showed that the project had correct knowledge of the requirement of maintenance as outlined in the URS. The OEM has developed the manuals at the earlier stage of the project from their templates as well as using off-the-shelve equipment manuals. This has eased the project challenges when it comes to maintainability of the plants. Although this is the case, it still remains that the level of detail has had an impact on the overall project performance.

8.1.2. CMMS Planning and Implementation Readiness

Data Acquisition is one of the key elements for a successful Computerized Maintenance Management System (CMMS). This has been a challenge for the project due to a number of reasons including delays in data or information, changes of systems, which meant migration (not well executed) from one database to another, document management not carried out correctly during migration process, which led to engineering having to revisit and verify data supplied per dossier.

The Training of users was conducted with delays in implementation, which is one of the factors for score reduction although the overall percentage. The limited training provided to certain department is not a good practice when the aim is to integrate all stakeholders to have synergy in project delivery.

The synchronization and details of data migrated from CMMS (SPO design data) to client CMMS (SAP for maintenance) is not evident as there are issues or challenges from the client side to source data from system.

8.1.3. Life Cycle Risk Control Readiness

The risk and safety measures were in place through the life cycle of the project because the organization remains robust on ensuring that the environment is safe and conducive. The confirmation is a good overall rating shown on Figure 23. There are issues, which relates to risk oversight that led to incidences, which have occurred in the past, and these incidence experienced during the project reveals that there is a need for improvement on the risk controls to ensure that the project avoid major damage to the property and injuries to personnel.

There are issues, which relate to oversight as seen with the incidences, which have occurred in the past also detailed on the Root Cause Analysis (RCA) on the report. These incidence experienced during the project reveals that there is a need for improvement on the risk controls to ensure that the project avoid major damage to the property and injuries to personnel.

The risk register has not been update progressively in the project life cycle and there are certain items, which are contributing to the performance of the final product

particularly on the steam generator, which shows oversight on the details of the risks in the project. This need to improve on future project and asset operational view is required when assessing the plausibility of the product promised during tendering stages.

8.1.4. Operational Readiness Planning and Implementation

The gap analysis in a form of lesson learnt for the project were documented progressively with a number of delays, which entails that the lesson learnt from the first power block has not been utilized in the successive block. The mitigation of the gaps identified has been ineffective throughout the project life cycle. This is evident in the RCA conducted in this study, which shows possibilities of preventing some of the instances by acknowledging the challenges faced, and ensuring that there are mitigations actions in place prior to commencement.

There are defects picked up, which have emerged from the construction activities. Some of the defects have not been resolved within the defect periods and this has a major contribution to the availability and reliability of the plant. The maintenance cost is one of the concerns, which the client has to deal with, as some of the failures are not justifiable during operation.

Design review procedure compared to an Asset Operational Readiness (AOR) document or Framework, is one of the key factors, which have major contribution to the reduced percentage of the AOR Readiness planning score. This is due to the delays in implementing a comprehensive model to deal with the operational readiness challenges as and when required in the life cycle of the project. There are also concerns in the details of the assessment during multiple reviews conducted such as end of phase review, integrated design review, and design freeze. The challenges of detailing during the review stages are evident with the multiple interface related issues experiences in all the fleet.

The RAM Study (RAMS) developed by the project does not provide sufficient details. The RAMS has not been updated with the defects and changes made during the course of implementation.

There are also issues with the integration of department to have all stakeholders aware of project drives and boundaries. There is evidence during the execution phase with department assuming roles, which are not necessarily included in their mandates.

The RCA, surveys and case study conducted has revealed that there are issues with the stakeholder engagement to ensure that there is clear business objective when going through all the phases to deliver a sound product, and this can be seen with the lack of knowledge on project related documentation and the expectation from each project participant. There are also issues with the integration of department to have all stakeholders aware of project drives and boundaries. This appears during the execution phase with department assuming roles, which are not necessarily included in their mandates.

8.1.5. AOR Support Planning and Implementation

The outsourced service for AOR were not executed to the required standards and has led to challenges, which are considered legacy issues of the projects causing a major upset to the delivery time of the project and the quality of the final product. This has also led to delays and issues with the documentation required for handover of the Asset.

The absence of some of the software and tools required for detailed assessment designs have also contributed to the outcome of the product due to induced redesign and re-engineering of designs improvements. The limitation with the tools entails that the assessment are conducted at a high-level for the purpose of initiating the execution stage of the project and this increases the risk associated with the assessed equipment.

Although this has a relatively high rating in comparison to the some of the assessment categories, AOR team roles and responsibility remains one of the major key element, which needs improvement. The Roles and responsibilities challenges emanate from the failure to clearly define the boundaries in the initial stage of the project when it comes to design engineering and AOR roles and responsibilities.

8.2. Qualitative Survey Questionnaire Discussion

This section of the report outlines the survey results acquired through the interviews carried-out. The survey categorized are shown in Table 12 and includes; general business overview, which deals with the existence of the AOR strategy, Organizational ability to deliver a sound product with the necessary documentation and spare parts for maintenance, competency of the resource to execute the set roles, as well as the perception on the effectiveness of the implemented AOR strategy.

The following gives the items highlighted during the survey conducted and incorporated in the AOR framework development as well as the discussions:

- The Organization approach for this capital project had gaps in term of ensuring that there is optimized interface, and that all the requirements validated through an AOR point of view. The finding, which relates to this area, is that the current documentation developed by and for the organization does not have sufficient information to eliminate ambiguity in implementation and commissioning phase of the project.

- The competency challenge is one of the items raised through the survey and this is one of the important parts of AOR effectiveness for product delivery. The competency to perform certain tasks materialized later in the project due to the need to resolve certain failures in the processes. The human resource strategy employed in the project was intentionally for the magnitude of the project; failure thereof resulted in a domino effect of failures to attend to the issues, which arose in the initial stages of the project.

- The client or the end-user has failed to plan for the inevitable reality, which calls for implementation of RBI having known the drive of the organization on maintainability of the fleet. The RBI implementation remains an issue due to failure to produce all the necessary maintenance and operation information. The failure to implement RBI has led to the project team having to intervene to ensure that the completion of the activity. The client should be part of the planning phase

of the project to eliminate issues of asset maintenance, which remains an issue in the project.

- The project has experience a high defects on the manufacturing stage, which has led to a need for high attention of the identified issues in order to reduce the failures during commercial operation. The defects identified affected the RAMS of the Asset and the project OEM has failed to revise the RAMS, as this does not feature in the contractual agreement.

- There are numerous issues, which have led to the hike in the budget for the new build projects and one of the main challenges relates to the payments of the milestones. The contract structuring was in a way that it assists in ensuring that the works performed translate to quality end-product. The lesson learnt from this is part of the amendment, which is inevitable to the AOR framework as it is clear that the details of the governing documents have contributed to the failure of the projects.

- The challenges experienced in the project, requires documenting to enable the organization to have sufficient knowledge when implementing future projects of similar magnitude with reduced risk of compromised product quality and performance.

- The tools used to perform AOR only exist in the PLCM but no implementation throughout the project life. The documents such as end of phase reviews and integrated design reviews serves as project gatekeepers, and this means that the risks are not curbed as they emanate but rather on the final stage of consolidated engineering activities. This is one of the issues, which results in granting of concessions due to the investment already committed.

- The project has developed an AOR tool, which looks at completeness of all engineering aspects of the project in order to ensure integrity of the Asset during operation. The tool comes later in the project due to all the challenges experienced, and this affects effectiveness of the tools. The failure of the tool to

ensure that the gaps are closed is due to its application, which comes as re-engineering mechanism in the project. The reactive approach on AOR of documenting or verifying completion of does not yield positive results even if the tool could be of great value.

- There is lot of energy invested on certain activities such as administrative and requires advance methods such as programme coding. There need to advancement could result in high productivity to deliver the product. The AOR matrix tool aforementioned is one of the examples of an e-system application. This system has failed to meet the minimum required standards of ensure transmission, reviewing, and approval of documentation, to easily access reports.

- The items such as Reliability Availability Maintainability Studies (RAMS) and Failure Mode Effect Criticality Analysis (FMECA) is required even for components and systems, which are not or a critical nature.

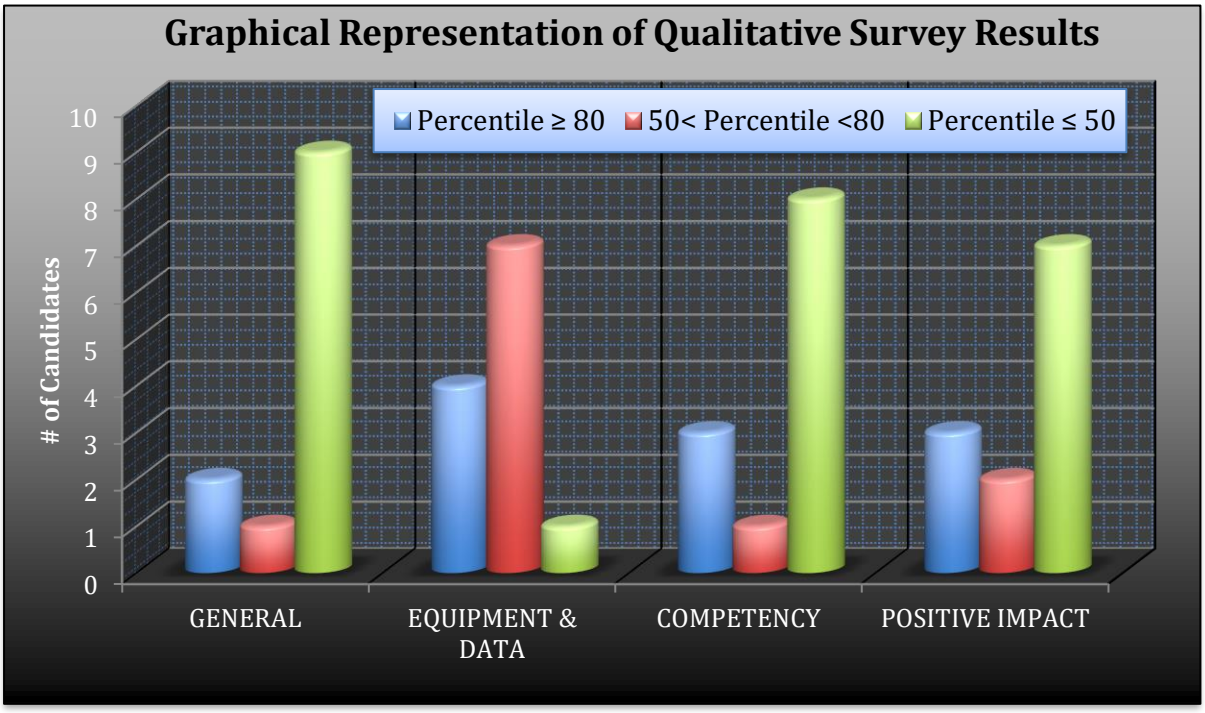

Figure 39: Graphical representation of quality survey results categorized in four sections.

The Figure 39 shows a graphical representation of the results tabulated in Table 15 and Table 16. The graphical representation gives a substantial view on the

discussion above as seen that the 4th category (AOR impact) remains one of the areas of concerns with huge improvement required.

		TYPE	Category 1: GENERAL	Category 2: EQUIPMENT AND DOCUMENTATION READINESS	Category 3: COMPETENCY READINESS	Category 4: OTHER (IMPACT)
1	INTERVIEWEE NUMBER 1	Engineer	50%	91%	50%	0%
2	INTERVIEWEE NUMBER 2	Engineer	33%	84%	50%	75%
3	INTERVIEWEE NUMBER 3	Management	0%	62%	20%	0%
4	INTERVIEWEE NUMBER 4	Management	100%	82%	80%	100%
5	INTERVIEWEE NUMBER 5	Management	25%	77%	67%	0%
6	INTERVIEWEE NUMBER 6	Management	67%	94%	100%	100%
7	INTERVIEWEE NUMBER 7	Engineer	0%	65%	10%	0%
8	INTERVIEWEE NUMBER 8	Management	17%	65%	100%	100%
9	INTERVIEWEE NUMBER 9	Engineer	0%	78%	20%	50%
10	INTERVIEWEE NUMBER 10	Project Lead	0%	71%	0%	0%
11	INTERVIEWEE NUMBER 11	Project Lead	100%	47%	20%	50%
12	INTERVIEWEE NUMBER 12	Management	33%	56%	10%	75%

Table 15: Quality Survey scoring per interview conducted.

Figure 39 and Table 15 gives a view of the candidates interviewed during the survey. The candidates' participation was through all the categories as shown on Figure 39 in order to have a clear view of the sentiments on the project. There was sufficient evidence that most of the candidate felt the general aspect, AOR skill–set & competency, and AOR impact were not the Organizational strong point. The partial implementation of AOR and delays in implementation of some AOR components might have a bearing on the dissatisfaction of the candidates, as there are various signs of failure in the system, which suggests non-existence.

INTERVIEWEE RESULT CATEGORIZATION				
	GENERAL	EQUIPMENT & DATA	COMPETENCY	POSITIVE IMPACT
Percentile ≥ 80	2	4	3	3
50< Percentile <80	1	7	1	2
Percentile ≤ 50	9	1	8	7

Table 16: Quality survey categorization for interviews conducted in percentile.

The results under “general” shows that execution was not at the minimum required and needs improvement. The “equipment and data” execution requires improvement although is evident that the some data requirement has been met. The “skills and competency” category requires huge improvement as it appears that most of the candidates feel that the organization has not invested sufficient in attending to this area. Lastly, the “impact” of the employed AOR shows a negative sentiment from the participants.

8.3. Summary of AOR Framework Output

The purpose of this section is to provide a summary of the AOR framework development and application. The purpose of the study was to develop an AOR framework, which can aid O&M team to manage the Asset delivered. Based on the intent of the study a comprehensive summary provides in-depth AOR framework possible areas of improvements:

The study fulfilled through development of an AOR framework and application thereof, and refined with the use of methodologies inclusive of RCA, AOR Assessment tools, Qualitative survey tool, and scoring systems, provides a basis for further improvement as shown in Figure 40. The AOR framework application to various case studies in line with PLCM, and embedded scoring system enables a stage wise assessment of each component to rank the performance of each AOR framework class. The stage wise provides an overview of the areas that require expansion to have a profound outcome.

The AOR framework application, results, and discussion in the research study provides confident in terms of impact of a well-developed AOR framework in capital project execution. The results obtained and discussed enables provides evidence of

the need to further decomposition into sub-components for enhancement of the results.

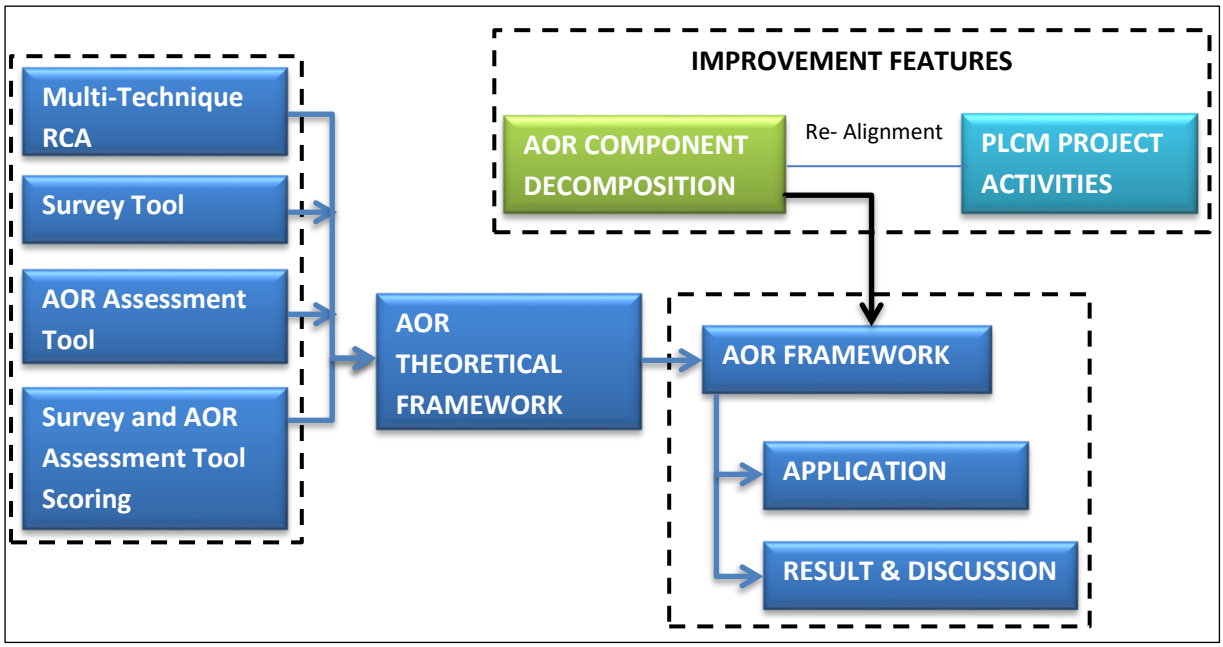

Figure 40: Schematic showing a summary of an AOR framework with Improvement features.

Figure 40 provides improvement features used to revise the AOR framework to obtain a more refined rating for each phase of the PLCM. The decomposition of the AOR framework component needs to re-align with project activities as detailed in the PLCM to allow for an optimized assessment approach.

9. CONCLUSIONS

The literature study covered in this document has detailed the AOR key elements throughout the PLCM with the consideration of interrelationship between the personnel, process, and the physical engineering assets. The elements of the AOR detailed include readiness to maintain the asset, computerized maintenance management system, the risk of delivering a project from an AOR view, support for AOR, which features AOR team and tools, and the main component which is the AOR strategy which caters for establishment of planning and implementation in order to effectively delivery a quality product.

The challenges or gaps which prompted the research of a non-integrated and poorly facilitated AOR function in one of the largest recent capital projects in Africa, have enabled a significant contribution to efforts to improve AOR theory and application. The first contribution which is evident in the research and has been used to assess the gaps, includes the development of a multi-technique RCA, which incorporates bow-tie, five whys, fish-bone, and Kepner-Tregoe, to establish the root causes of AOR related deficiencies.

The second contribution is the development of a best-practice AOR framework, which incorporates various concepts found in the literature to optimize the existence of each AOR component in a PLCM. The Framework, in the form of a process, leads to the development of the AOR framework assessment and refinement tool. The key noticeable feature of the Framework and the Framework assessment tool, which differs from the existing AOR frameworks, includes the following:

- Stepwise assessment using PLCM Stages embedded with a scoring system. The assessment and scoring uses an enhanced AOR as detailed in the study discussions.
- The integrated AOR multi-disciplinary Framework applies to various entities or project due to the diversified approach used in the literature review.
- The research also shows that the assessment tool has the capability to ascertain the performance of all categories of AOR by weighing components of different categories at all the stages of a PLCM.

Thirdly, the research also included an intensive assessment of various elements within the boiler plant of a mega coal power generation plant project, as a means of demonstrating the feasibility and significance of the proposed Framework and assessment tool.

The AOR assessment tool with an embedded scoring system enhancement with the use of multi-technique RCA and qualitative survey has shown that each category is significant to achieve a successful product delivery from an AOR perspective. In addition, the study shows that an AOR framework assessment tool requires a scoring model that caters for each phase of a PLCM for all categories. This ensures that an organization or a project appreciates the magnitude of the risks induced by gaps identified in each phase of PLCM.

The assessment shows that there were implications for inadequate development and implementation of any of the items in the proposed Framework, derived from the diversified literature study conducted. The implication can range from re-work during manufacturing and construction, poor product quality delivery, poor performance post commissioning, and overall cost overruns as detailed in the discussion.

The assessment conducted also provided conclusive evidence that it is vital for a project to have a well-defined AOR process or Framework with all the required categories. This will aid a project to realize its potential and yield positive results, which will ultimately benefit an organization from a quality product delivery, cost reduction perspective, and O&M of engineering asset.

10. RECOMMENDATION AND PROPOSED FUTURE RESEARCH

The recommendations and future research proposed are as follows but not limited to the following point listed below:

- The AOR framework has provided details in terms of the components assessed to ascertain the score applicable to each phase. Although this is the case, it is important to further detail the components as part of future research work to give insight on each component and the level of assessment required.
- An extended validation of the framework is required from other industrial engineering assets as an expansion to this research study. The validation should include other fields, which have different Asset delivery approach and perception to ensure that the Framework is diverse enough to deal with all the types of situation.
- The framework has been validated to a certain extend as discussed in the report with few limitation which needs to be addressed in future work. The recommendation in this regard is to apply the framework on a new real project (from the feasibility phase to Commissioning phase) to ascertain the feasibility and usefulness.
- The implementation of the Framework in a real project is one of the key to validate cost realization as suggested by the literature review for deploying a well-defined AOR framework. The validation of the cost is an additional consideration to an entity to implement this specific AOR framework. A recommendation is that a cost modeling study conducted to baseline direct cost and schedule impact due to AOR in the organization in order to realize the benefits thereof.

11. REFERENCES

(1) Aboelmaged, M. G., 2014. Predicting e-readiness at firm-level: An analysis of technological,. *International Journal of Information Management organizational and environmental (TOE) effects on e-maintenance readiness in manufacturing firms,* Issue 34, pp. 639-651.

(2) Acfield, A. . P. & Weaver, R. . A., 2012. *Integrating Safety Management through the Bowtie Concept A move away from the Safety Case focus.* Canberra, Proc. of the Australian System Safety Conferrence (Airservices Australia).

(3) AL-MAZROUIE, J. R. B. R., 2017. *An Investigation in to the Impact of Operational Readiness Factors on the Success of Airports Projects in the UAE,* Dubai: The British University.

(4) Barnes, A., 2018. *Guideline: Operations Requirements to add Assets,* s.l.: Horizon Power Corporation.

(5) Levovnik, D. & Gerbec, M., 2018. Operational readiness for the integrated management of changes in the industrial organizations – Assessment approach and results. *Safety Science,* Issue 107, pp. 119-129.

(6) Mo, J. P. T. & Saidi, M. S. A., 2014. An Approach to Manage and Evaluate Engineering Asset Performance. *Global Journal of Researches in Engineering,* 14(1), pp. 15-28.

(7) Olechowski, A., Eppinger, S. D. & Joglekar, N., 2015. *Technology Readiness Levels at 40: A Study of State-of-the-Art Use, Challenges, and Opportunities.* USA, Proceedings of PICMET '15: Management of the Technology Age.

(8) Sauser, B., Ramirez-Marquez, J., Verma, D. & Gove, R., 2006. From TRL to SRL: The Concept of Systems Readiness Levels. *Conference on Systems Engineering Research*, 7-8 April , Issue 126, pp. 1-10.

(9) Andersen, B. & Fagerhaug, T., 2006. *Root Cause Analysis, Second Edition: Simplified Tools and Techniques.* 2nd Edition ed. Milwaukee: ASQ Quality Press.

(10) Animah, I. & Shafiee, M., 2018. *A framework for assessment of Technological Readiness Level (TRL) Commercial Readiness Index (CRI) of asset end-of-life strategies.* Bedford, ResearchGate, pp. 1767-1773.

(11) Asia Industrial Gases Association, 2017. *PROCESS SAFETY MANAGEMENT FRAMEWORK,* Singapore: Asia Industrial Gases Association.

(12) Austin, M. F. & York, D. M., 2015. System Readiness Assessment (SRA) An Illustrative Example. *Procedia Computer Science,* Issue 44, p. 486 – 496.

(13) Bakke, K., 2017. *Technology readiness levels use and understanding,* South-East Norway: INCOSE.

(14) Balcke-Dürr, n.d. *Pulse Jet Fabric Filter.* [Online] Available at: https://www.balcke-duerr.com/products/filter-systems/pulse-jet-fabric-filters/
[Accessed 17 August 2019].

(15) Bond, B., 2017. *OPERATIONAL READINESS WITHOUT DELAY,* Houston: Training & Development Systems, Inc. (TDS).

(16) Chapman, R. E., 2001. *Benefits and Costs of Research: A Case Study of Construction Systems Integration and Automation Technologies in Commercial Buildings,* Gaithersburg: National Institute of Standards and Technology.

(17) Christison, M., 2017. *Operational Readiness – Launching Capital Projects Successfully in Local Government,* s.l.: Beca Limited.

(18) Cool, C. & Bor Ng, K., 2013. *Recent Development in the Design, Construction, and Evaluation of Digital Libraries.* Hershey: Information Science Reference (an imprint of IGI Global).

(19) DiStefano, R., Goetz, W. & Storino, B., 2018. *Reliabilityweb: Operational Readiness: Bridging the Gap Between Construction and Operations for New Capital Assets.* [Online] Available at: https://reliabilityweb.com/articles/entry/bridging_the_gap_between_construction_and_operations/
[Accessed 29 August 2018].

(20) DOE, U., 2010. *Planning and Conducting Readiness Reviews,* Washington: U.S. National Technical Information Service.

(21) Eskom Medupi Power Station Project, 2014. *New Build Programme.* [Online]
Available at: https://www.eskom.co.za/Whatweredoing/NewBuild/MedupiPowerStation/Doc

uments/GoodNews02Dec2014.pdf
[Accessed 17 August 2019].

(22) Fakher, H. B., Nourelfath, M. & Gendreau, M., 2017. Integrating Production, Maintenability and Quality: a Multi-Period Multi-Production Profit-Maximization Model. *Interuniversity research Centre on Enterprise Networks, Logistics and Transportation (CIRRELT),* Issue 59, pp. 1-29.

(23) Flour Corporation, 2011. *Operational Readiness & Start-Up Support,* s.l.: Flour Corporation.

(24) Gardner, D. G., 2001. *Operation Readiness - Is your system More "Ready" Than Your Environement?.* Nashville, Tenn., USA, Project Management Institute Inc., First to the Future: Proceedings of the 32 Annual Seminars & Symposium.

(25) Gerbec, M., 2017. Management of technical and organizational changes. *Safety and Reliability – Theory and Applications – epin & Briš (Eds),* pp. 1595-1602.

(26) Hendershot, D., 2014. Process safety:Operational readiness. *Journal of Chemical Health & Safety,,* pp. 44-45.

(27) Jacobi, J., 2009. *Generator Operational Readiness: Preparing for Plant Start Up and Operations,* Raleigh: ScottMadden.

(28) Jahnig, D. & Agoston, J., 2016. *RISK MANAGEMENT – IS YOUR CAPITAL PROJECT READY TO DELIVER BUSINESS VALUE?,* s.l.: Navigant Consulting.

(29) Kajko-Mattsson, M., Karim, R. & Mirijamdotter, A., 2010. Fundamentals of the eMaintenance Concept. *The 1st international workshop and congress on eMaintenance*, 22-24 June.

(30) Kececioglu, d., 2003. *Maintenability, Availability, & Operational Readiness Engineering Handbook.* 1st ed. Pennsylvania: DEStech Publications.

(31) Kingston-Howlett, J., Frei, R., Garforth, A. & Lindhout, P., 2016. More than process restart/pre-start: Operational readiness – alive and kicking. *IChemE Hazard 26,* Issue 161, pp. 1-11.

(32) Knoxville, T. N. et al., 2015. *Interconnection of Distributed Generation in New York State: A Utility Readiness Assessment,* New York: Electric Power Research Institution (EPRI).

(33) Koko, M. M., Musel, J. & Fouiloux, J.-P., 2009. The New Power Plant Projects of Eskom: An Overview of Medupi and Kusile Power Plants. *VGB PowerTech · Autorenexemplar,* p. 35.

(34) Krauss, E., 2014. How Does Operational Readiness Assist in Asset Management: It Surely is an Operations Function?. *Australian Journal of Multi-disciplinary Engineering,* Volume 11, pp. 1-11.

(35) Lofgren, E. V., Cooper, S. E., Kurth, R. E. & Phillips, L. B., 1991. *A Process for Risk-Focused Maintenance.* Washington: Science Applications International Corporation.

(36) Mabelo, P. B. & Sunjka, B. P., 2017. APPLICATION OF SYSTEMS ENGINEERING CONCEPTS TO ENHANCE PROJECT LIFECYCLE METHODOLOGIES. *South African Journal of Industrial Engineering,* 28(3), pp. 40-55.

(37) Maletic, D., Al-Najjar, B., Maletic, M. & Gomiscek, B., 2014. The role of maintenance in improving company's competitiveness and profitability: a case study in a textile company. *Journal of Manufacturing Technology Management,* 25(4), pp. 441-456.

(38) Mokhatab, S., Poe, W. A. & Mak, J. Y., 2015. *Handbook of Natural Gas Transmission and Processing: Maximizing Profitability of Gas Plant Assets.* 3rd Edition ed. Oxford: Elsevier Inc: Gulf Professional Publishing.

(39) Moubray, J., 1997. *Reliability-centered Maintenance.* 2nd ed. Great Britain: Butterworth Heinemann.

(40) Muller , A., Marquez, A. & Iung, B., 2008. On the concept of eMaintenance: Review and current research. *Journal of Reliability Engineering and System Safety,,* 93(8), pp. 1165-1187.

(41) National Institute of Standards and Technology, 2006. *NIST construction project survey,* USA: s.n.

(42) National Institute of Standards and Technology, 2014. *NIST Framework and Roadmap for Smart Grid Interoperability Standards,* s.l.: NIST Special Publication 1108R3.

(43) Nertney, R. J., 1987. *Process Operational Readiness and Operational Readiness Follow-On,* Idaho Falls: System Safety Development Center EG$G Idaho, Inc.

(44) Network Rail, 2017. *Product Acceptance Service: Network Rail Safety Technical and Engineering,* London: Network Rail.

(45) Office of the Deputy Assistant Secretary of Defense for Systems Engineering, 2017. *Best Practices for Using Systems Engineering Standards (ISO/IEC/IEEE 15288, IEEE 15288.1, and IEEE 15288.2) on Contracts for Department of Defense Acquisition Programs,* Washington: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics.

(46) Okes, D., 2009. *Root Cause Analysis: The Core of Problem Solving and Corrective Action.* 1st ed. Milwaukee: ASQ Quality Press .

(47) OSD Manufacturing Technology Program, 2011. *Manufacturing Readiness Level (MRL) Deskbook,* Virginia: Department of Defence.

(48) Parmenter, D., 2015. *Key Performance Indicator: Developing, Implementing, and Using Winning KPIs.* 3rd Edition ed. New Jersey: John Wiley & Sons, Inc.

(49) Richter, K., 2018. *Operational Readiness: Incident free, seamless transitions from capital project to reliable operations.,* Houston: PILKO & ASSOCIATES.

(50) Rooney , J. J. & Vanden Heuvel, L. N., 2004. *Root Cause Analysis for Beginners,* Knoxville: ABSG Consulting Inc..

(51) Ross, S., 2016. *APPLICATION OF SYSTEM AND INTEGRATION READINESS LEVELS TO DEPARTMENT OF DEFENSE RESEARCH AND DEVELOPMENT,* Kirtland: The Defense Acquisition University.

(52) Seymour, T. & Hussein, S., 2014. The History Of Project Management. *International Journal of Management & Information Systems,* 18(4).

(53) Sobbe, W., 2013. *Docplayer (VKK Standardkessel Köthen GmbH document).* [Online]
Available at: https://docplayer.net/10954294-Steam-and-hot-water-boiler-systems-for-industrial-and-municipal-power-generation-dr-ing-wolfgang-sobbe-vkk-standardkessel-kothen-gmbh.html
[Accessed 24 October 2018].

(54) Transport Asset Standards Authority, 2018. *Asset Handover Requirements,* New South Wales: State of NSW.

(55) Tugurlan, C., Kirkham, H. & Chassin, D., 2011. *Software Technology Readiness for the Smart Grid.* Richland, WA, Pacific Northwest National Laboratory Advanced Power and Energy Systems.

(56) US Department of Energy, 2010. *Planning and Conducting Readiness Reviews,* Washington: US Department of Energy.

(57) Voicu, I. et al., 2018. *Risk management with Bowtie diagrams.* Constanta, IOP Publishing.

(58) Wannenburg, J., 2016. *Asset Management Framework,* s.l.: Anglo American Platinum (Internal document).

(59) Wannenburg, J., 2016. *Asset Strategy & Reliability,* s.l.: Anglo American Platinum (Internal document).

(60) Wheeler, D. & Ulsh, M., 2010. *Manufacturing Readiness Assessment for Fuel Cell Stacks and Systems for the Back-up Power and Material Handling Equipment Emerging Markets,* Colorado: National Renewable Energy Laboratory.

(61) Wienker, M., Henderson, K. & Volkerts, J., 2016. The Computerized Maintenance Management System: An essential Tool for World Class Maintenance. *Procedia Engineering,* Issue 138, pp. 413-420.

(62) Yap , J. B. H., Abdul-Rahman, H. & Chen, W., 2017 . Design Change Dynamics in Building Project: From Literature Review to A Conceptual Framework Formulation. *Journal of Surveying, Construction and Property (JSCP),* 8 (1).

(63) Yap, J. B. H., Abdul-Rahman, H. & Wang, C., 2015. *Impacts Of Design Changes on Construction Project Performance: Insights From A Literature Review.* Malaysia, In 14th Management In Construction Researchers' Association (MiCRA 2015) Annual Conference and General Meeting.

(64) Zuo, M. J., Mathew, J., Ma, L. & Huang, H. Z., 2016. *Engineering Asset Management 2016.* Cham Switzerland: Springer International Publishing.

12. ACKNOWLEDGEMENT

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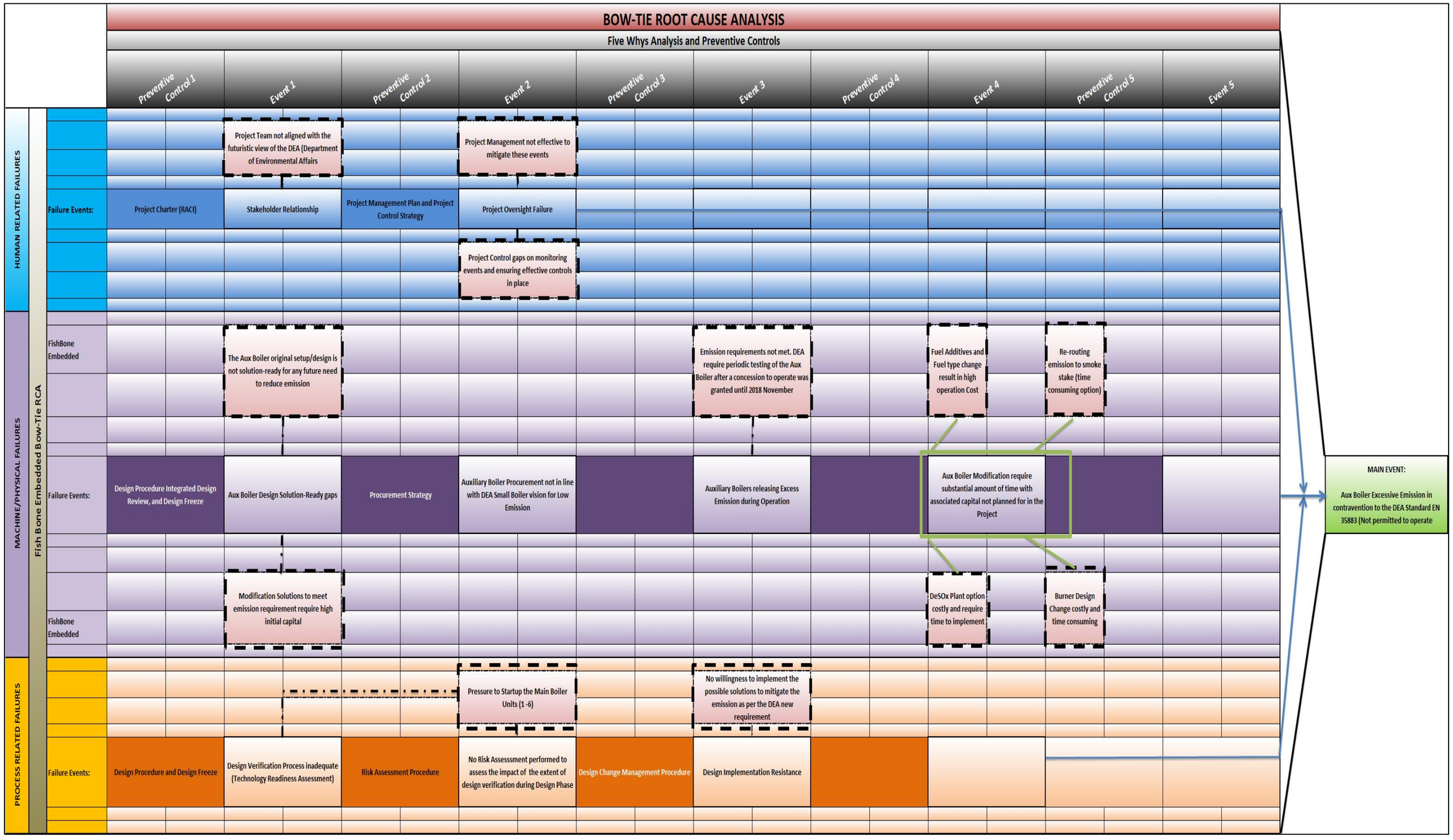
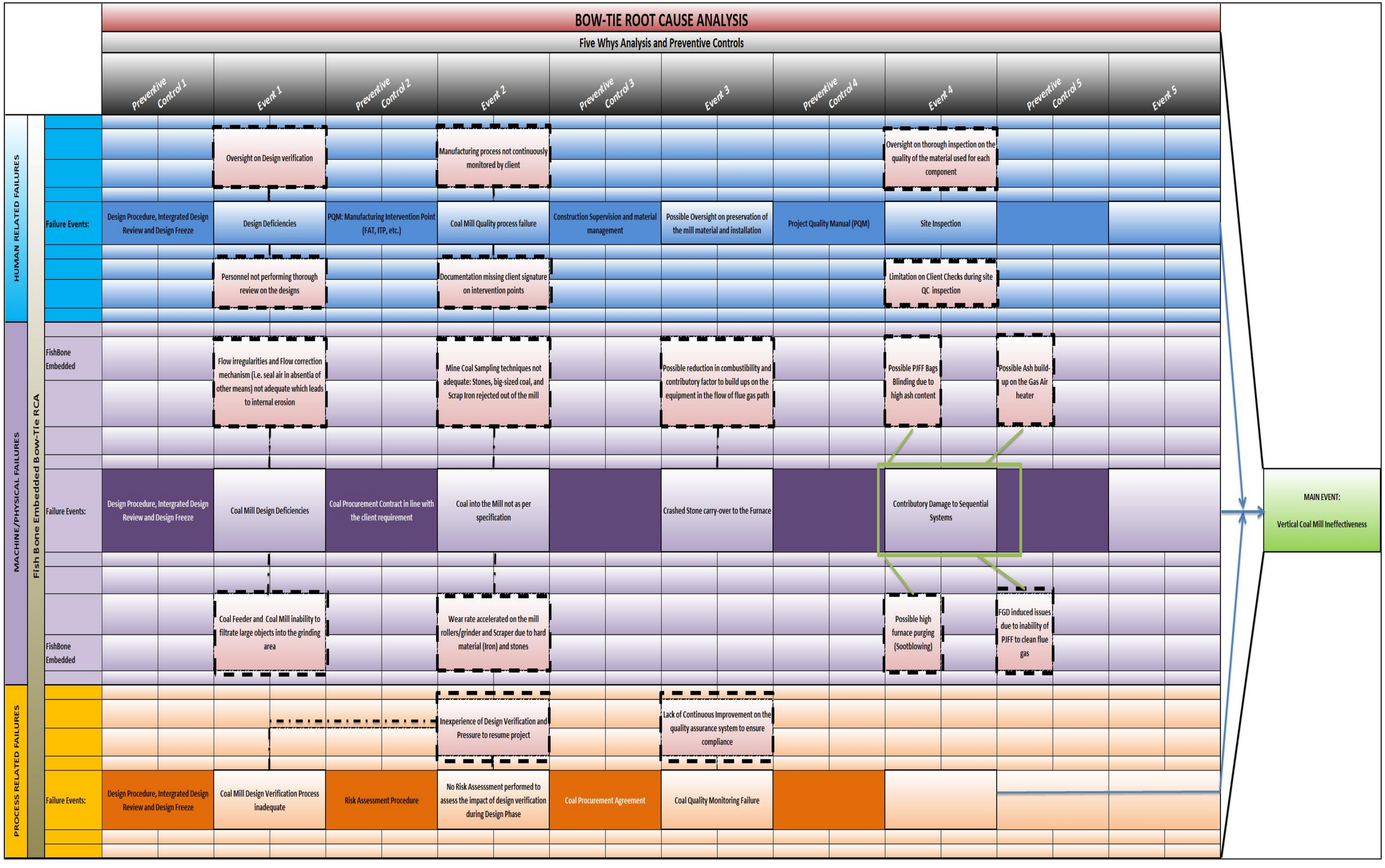
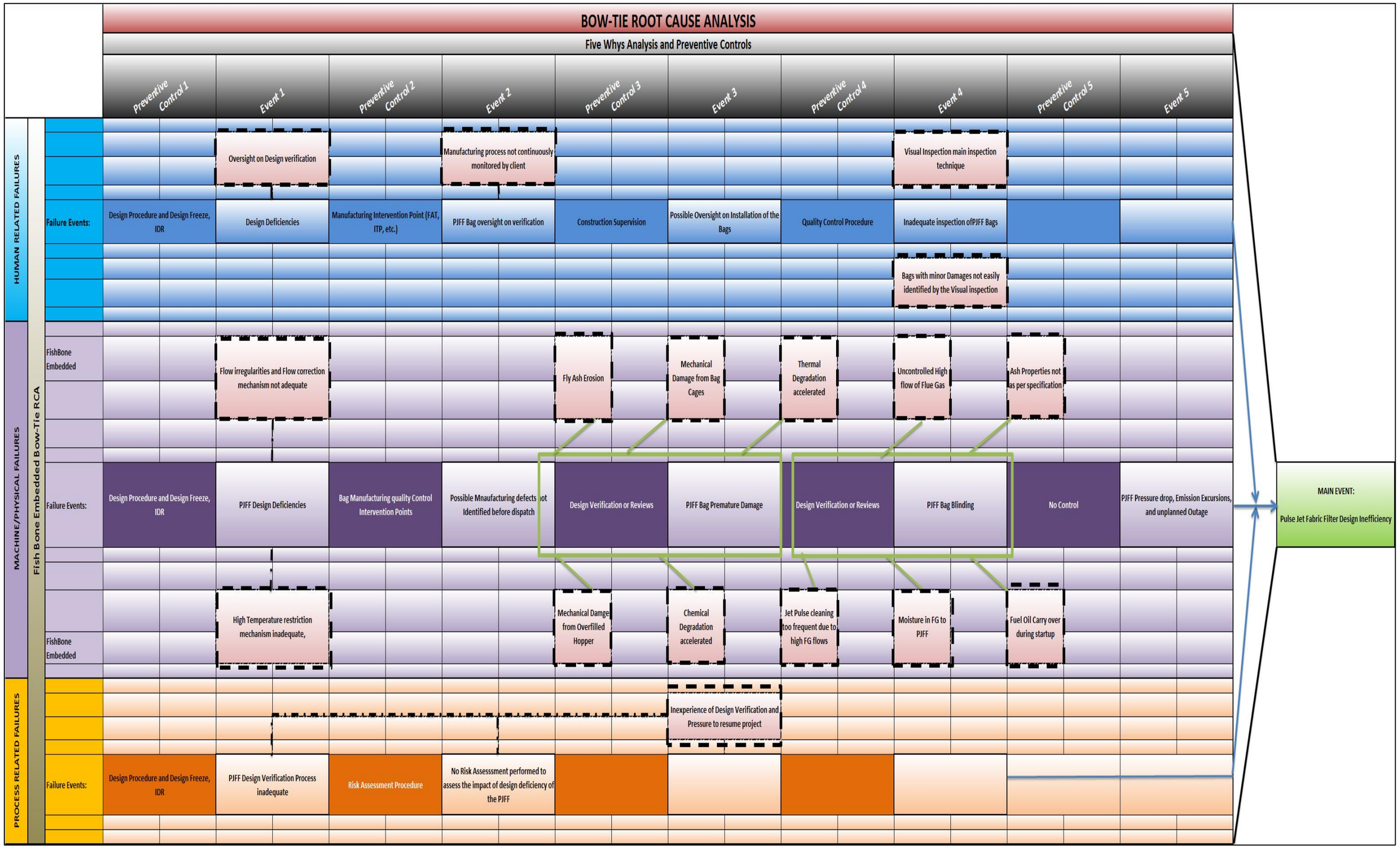
13. APPENDIX A1: AUXILIARY BOILER ROOT CAUSE ANALYSIS



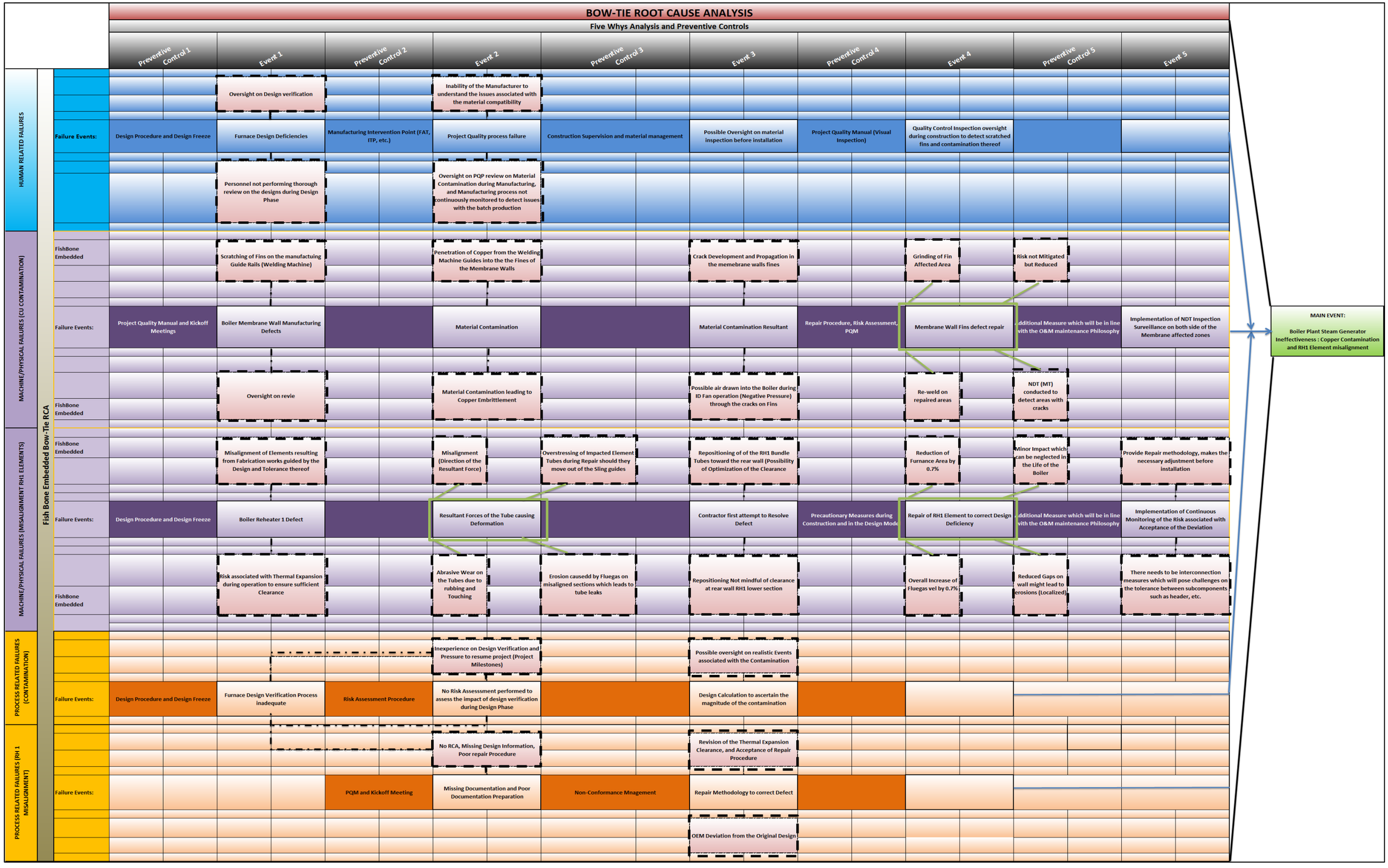
14. APPENDIX A2: BOILER COAL MILL ROOT CAUSE ANALYSIS



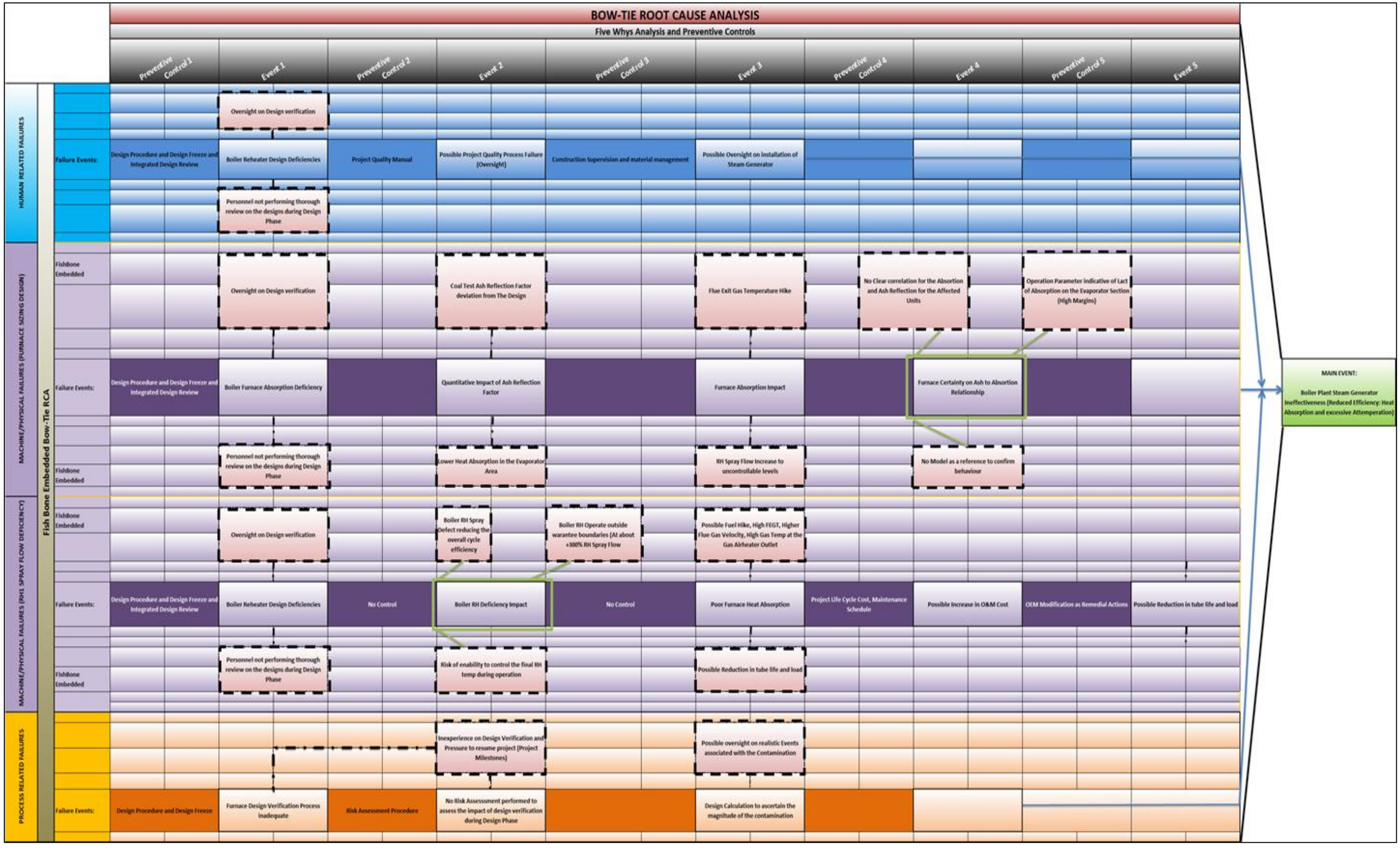
15. APPENDIX A3: PJFF ROOT CAUSE ANALYSIS



16. APPENDIX A4: STEAM GENERATOR ROOT CAUSE ANALYSIS PART 1



17. APPENDIX A5: STEAM GENERATOR ROOT CAUSE ANALYSIS PART 2



18. APPENDIX B: OVERALL BOILER CASE STUDY ASSESSMENT

BOILER PLANT AOR CASE STUDY (AUXILIARY BOILER/ COAL MILL/ BOILER FURNANCE/ FABRIC FILTER PLANT)																	
Item #	Item Description	Maintenance Planning and Readiness (Weigh 20%)															
		PROPOSED METHOD															
		Conceptual Phase				Definition Phase				Execution/Implementation phase				Commissioning /Takeover Phase			
1	Strategy Development	Business Vision Definition and Project Charter Development Maintenance Development Initiation				Maintenance Resource Plan Development Production Performance Detailing Production Risk Plan Development Spare Part Equipment Plan Development				Maintenance Strategy Updates Resource Plan Updates Spare Part Procurement and Preservation and Storage				Maintenance Strategy Finalization and Approval			
2	Data and Information Acquisition	Definition of data and Information required				Acquisition of Detailed Maintenance Data Data Categorization and Assessment				Update Maintenance Database Assess data and re-categorize							
3	Maintenance Strategy control and monitoring	Define controls and monitoring of Maintenance strategy								Non-Conformance Management to update maintenance Strategy							
4	Record and Documentation Control	Record Plan Definition								Information Compilation and Record Verification				Maintenance Data and OEM Manual Handover As-Build Information Handover			
5	Maintenance Cost Plan									Maintenance Cost Plan Development							

		NEW BUILD PROJECT METHOD															
		Conceptual Phase			Definition Phase			Execution/Implementation phase			Commissioning /Takeover Phase			Final Score		
1	Strategy Development	Business Vision Definition and Project Charter Development **(Project Chart Fulfilled to address business needs and objectives)**	✓	87%			67%			67%			33%	13.3%	67%	Need Improvement
		Maintenance Development Initiation **(User Requirement Specification (URS) and Project Contract)**	✓		Maintenance Resource Plan Development **(Fulfilled during execution stage)**	!		Maintenance Strategy Updates **(Completed)**	✓		Maintenance Strategy Finalization and Approval **(Partially Fulfilled)**	✗				
					Production Performance Detailing: Capacity of a system to meet demand) **(This was fulfilled through development of HAZOP Study, RAM Study-not detailed, URS)**	✓		Resource Plan Updates **(Partial fulfilled, deployment of client maintenance team)**	✗							
					Production Risk Plan Development **(FMECA Design Liaison Meetings)**	✓											
					Spare Part Equipment Plan Development **(Partially fulfilled)**	✗		Spare Part Procurement and Preservation **(Fulfilled during Execution and Takeover - Partially)** and Storage **(Storage requirement partially fulfilled - maintenance spare storage incomplete)**	✗							
2	Data and Information Acquisition	Definition of data and Information required **(Vendor Document Submittal Schedule VDSS, and URS, Project Contract)**	✓		Acquisition of Detailed Maintenance Data **(Initiated during Execution phase as agreed with delays)**	!		Update Maintenance Database **(Update of database ongoing with delays of submissions)**	!							
					Data Categorization and Assessment **(Partially Fulfilled)**	✗		Assess data and re-categorize **(Engineering team performing the function if and when there are changes - Handover Design Report (HDR))**	!							
3	Maintenance Strategy control and monitoring	Define controls and monitoring of Maintenance strategy **(Design Review Procedure (DRP))**	!					Non-Conformance Management to update maintenance Strategy **(Construction Quality Manual (CQM) / Project Quality Manual (PQM))**	✓							
4	Record and Documentation Control	Record Plan Establishment **(Project Design manual and Project Contract)**	!					Information Compilation and Record Verification **(Fulfilled Handover Design Report (HDR))**	✓		Maintenance Data and OEM Manual Handover **(Progressive submissions with delays leading to Plant operation without all necessary documentation)**	✗				
											As-Build Information Handover **((Progressive submissions with delays leading to Plant operation without all necessary documentation)**	✗				
5	Maintenance Cost Plan							Maintenance Cost Plan Development **(Incorporated in clients budget with issues of spares due to oversight on specification)**	✗							

ASSESSMENT REMARKS: AUXILARY BOILER, COAL MILL, BOILER FURNACE, & FABRIC FILTER PLANT
The assessment done is applicable to all the case studies which are discussed in the case study section of the report in detail. 1. Maintenance Philosophy was delayed, the implementation and detailing took place mostly in the execution phase of the project. 2. There are some of the minimum requirement as per the proposed method which have been met with delays on the spare part plan and partial implementation of maintenance plan and costing associated. This has a major impact on the final scores of the maintenance readiness which has an out come of 67% implying that there is a need to improve on the on the areas of maintenance in future project to avoid challenges of taking over and operating the asset. The failure to have a comprehensive maintenance philosophy on time has led to issues associated with procurement as the client specification does not cover extensively the procurement of spare part for the purpose of maintenance and operation. although the specification does mention maintainability of the plant is difficult conclude on the details of spare part supply apart from submission of specific data to assist with procurement of equipment for maintenance. 3. There are some decisions made which did not factor the possibilities of late data/information submissions and this can be associated to lack of experience on mega projects and hindrances thereof. 4. Resource Plan for Maintenance of the Asset is one of the component which required major improvement should there be any future projects. This was factored partially with late involvement to the project, which led to issues with taking over the plan and also not sufficient period to understand the issues associated with the project before operation.

BOILER PLANT AOR CASE STUDY (AUXILIARY BOILER/ COAL MILL/ BOILER FURNANCE/ FABRIC FILTER PLANT)

Item #	Item Description	Computerised Maintenance System preparation and Integration (Weigh 15 %)		
		PROPOSED METHOD		
		Conceptual Phase	Definition Phase	Execution/Implementation phase	Commissioning /Takeover Phase
1	Business Project Charter	Maintenance Requirement	Define Standard Operating Process Develop Implementation Plan		
2	Record and Documentation Control	Information Requirement Definition			
3	Maintenance System	CMMS Process Flow Development	Detail the Process Flow Activities	CMMS Process Finalization Initiate Data Input Configuration of System	Commission System
4	Resource Planning	Implementation Team Establishment	Establish the Training Requirement	Provide Continuous training to the System Users	
5	CMMS Monitoring and Control			Establish System Audit Requirements	Process and Data Audit

		NEW BUILD PROJECT METHOD														
		Conceptual Phase			Definition Phase			Execution/Implementation phase			Commissioning /Takeover Phase			Final Score		
1	Business Project Charter	Maintenance Requirement **(User Requirement Specification (URS) and Project Contract)**	✓		Define Standard Operating Process **(Fulfilled)**	✓										
					Develop Implementation Plan **(Already in existence)**	✓										
2	Record and Documentation Control	Information Requirement Definition **(User Requirement Specification (URS) and Project Contract)**	✓													
3	Maintenance System	CMMS Process Flow Development **(SAP System adopted from organization's fleet)**	✓	83%	Detail the Process Flow Activities **(Fulfilled)**	✓	92%	CMMS Process Finalization **(Fulfilled SAP&SPO)**	✓	80%	Commission System **(Fulfilled)**	✓	83%	12.7%	84%	Good
								Initiate Data Input **(Parially Fulfilled with issue with migration of information from one system to another)**	✗							
								Configuration of System **(Fulfilled to meet organization requirement)**	✓							
4	Resource Planning	Implementation Team Establishment **(Contractor System use and migrated to SPO Document and Design System - Resources already identified but not sufficient for data capturing)**	✗		Establish Training Requirement **(Fulfilled during execution phase of the project)**	!		Provide Continuous training to the System Users **(As and when required)**	!							
5	CMMS Monitoring and Control							Establish System Audit Requirements **(Quality Audit conducted in line with ISO Standards)**	✓		Process and Data Audit **(Conducted by Engineering using HDR)**	!				

ASSESSMENT REMARKS: AUXILARY BOILER, COAL MILL, BOILER FURNACE, & FABRIC FILTER PLANT
1. Data Acquisition is one of a key element to a successful Computerized Maintenance Management System (CMMS), and this has been a challenge for the project due to a number of reasons including delays in data or information, changes of systems which meant migration (not well executed) from one database to another, document managment not carried out correctly during migration process which led to engineering having to revisit and verify data supplied per dossier.
2. TheTraining of users was conducted with delays in implementation which is one of the factor for score reduction although the overall percentage is at 84 percent. The training was provided to certain department which is not a good practice when the aim is to integrate all stakeholder to have synergy in project delivery.
3. The resource plan for documentation plan for all project technical data shows gaps in terms of profiling the skills and knowledge associated with the data categorization and assessment. This is evident with the data input carried out during migration revealing failure to capture data according to dossiers provided.
4. The synchronization and details of data provided of one of the CMMS (SPO Design Data) to Client CMMS (SAP Maintenance) is not evident as there are issues or challenges from the client side to source data from system.

BOILER PLANT AOR CASE STUDY (AUXILIARY BOILER/ COAL MILL/ BOILER FURNANCE/ FABRIC FILTER PLANT)

Item #	Item Description	Life Cycle Risk Control Readiness (Weigh 20%)											
		PROPOSED METHOD											
		Conceptual Phase			Definition Phase			Execution/Implementation phase			Commissioning /Takeover Phase		
1	Business SHEQ Policy	SHEQ Contract Development EIA Study Project Due Diligence											
2	Risk Management	Establish Risk Assessment Method Development of Risk Register Establish SHE & Q Management System			Update Risk Register Risk Strategy Development Detail Acceptance Criteria Definition Performance Indicator Disaster Recovery Plan Permitting Requirement Definition			Update Risk Register Permit Issuing and Permit Control			Safety Clearance and Issue Compliance Certificate		
3	Risk Manpower	Risk Team Establishment (Done)			Risk Team Training			SHEQ Awareness Training Provide Oversight			Provide Oversight on Commissioning Activities		

		NEW BUILD PROJECT METHOD															
		Conceptual Phase			Definition Phase			Execution/ Implementation phase			Commissioning /Takeover Phase				Final Score		
1	Business SHEQ Policy	SHEQ Contract Development **(Definition phase and Execution phase - PQM/CQM and SHE Policy)**	!														
		EIA Study **(Completed)**	✓														
		Project Due Diligence **(pre-feasibility completed)**	✓														
2	Risk Management	Establish Risk Assessment Method **(Project Risk Register)**	✓	95%			90%			83%	Safety Clearance and Issue Compliance Certificate **(Fulfilled)**	✓	67%		17.7%	88%	Good
		Development of Risk Register **(Project Risk Register)**	✓		Update Risk Register **(Partially)**	✗		Update Risk Register **(Partially)**	✗								
		Establish SHE and Quality Management System **(Organization's SHE and Quality management system)**	✓		Risk Strategy Development **(completed)**	✓											
					Detail Acceptance Criteria Definition **(Completed)**	✓											
					Performance Indicator **(completed)**	✓											
					Disaster Recovery Plan **(Blackout Procedure, and Insurance policy)**	✓											
					Permitting Requirement Definition **(Plan Safety Regulation, Gird code, Department of Labour, Pressurized Equipment Regulation PED/PER, Emission regulation, and Water License)**	✓		Permit Issuing and Permit Control **(Project Safety department)**	✓								
3	Risk Manpower	Risk Team Establishment **(Integrated into the Engineering team)**	✓		Risk Team Training **(Fulfilled and continuous improvement as and when required)**	✓		SHEQ Awareness Training **(Safety and Quality awareness training and toolbox talk)**	✓								
								Provide Oversight **(Risk and Safety team)**	✓		Provide Oversight on Commissioning Activities **(Partial, some incident show lack of supervision)**	✗					

ASSESSMENT REMARKS: AUXILARY BOILER, COAL MILL, BOILER FURNACE, & FABRIC FILTER PLANT
1. Most of the Risk and Safety Measures were in place through the life Cycle of the Project, this can be confirmed with the good overall rating of 88 percent. 2. There are issues which relates to risk oversight as it can be seen with the incidences which have occured in the past also detailed on the Root Cause Analysis on the report. These incidence experienced during the project reveals that there is a need for improvement on the risk controls to ensure that the project avoid major damage to the property and injuries to personnel. 3 The Risk Register has not been update progressively in the project life cycle and there are certin items which are contributing to the performance of the final product particularly on the steam generator which shows oversight on the details of the risks in the project. This needs to improved on future project and asset operational view needs to be factored when assessing the plausability of the product promissed during tendering stages.

BOILER PLANT AOR CASE STUDY (AUXILIARY BOILER/ COAL MILL/ BOILER FURNANCE/ FABRIC FILTER PLANT)

Item #	Item Description	Operational Readiness Planning and Implementation (Weigh 35%)								
		PROPOSED METHOD								
		Conceptual Phase			Definition Phase			Execution/ Implementation phase		Commissioning /Takeover Phase
1	AOR Strategy	AOR requirement and Objectives conceptualization AOR Strategy Concept Development			Detailed AOR Strategy Development Strategy Implementation Plan AOR Business driven changes Management Plan Establishment AOR Review Plan Development			AOR Strategy Finalization and update AOR Strategy Execution Commissioning Process Development Recording of Project Changes RAM Process Establishment and Review		Takeover Support AOR and Commissioning Support Change Documentation and As-Build Updates NCR Management and Documentation Review AOR Completeness Plant Optimization and Operation threshold establishment
2	AOR Funding and Budget	Funding and Budget Establishment			AOR budget Baselining					
3	Communication Structure	AOR Communication Plan Development			Establish Service delivery agreement Establish Operating Level Agreement					
4	Gap Analysis				Gap Reviews Methodology Establishment			Establishment of GAPs Mitigation Plan		Closure of Punch Items
5	Monitoring and Control				AOR Project Scheduling			AOR Project Control Oversight		Oversight and Supervision of Commissioning activities

		NEW BUILD PROJECT METHOD											
		Conceptual Phase		Definition Phase		Execution/ Implementation phase		Commissioning /Takeover Phase			Final Score		
1	AOR Strategy	AOR requirement and Objectives conceptualization **(Design Review Procedure which was developed in the definition phase details the requirement of having an operational sound product)**						Asset Takeover Support **(Takeover team challenges to takeover plant)**					
		AOR Strategy Concept Development **(Design Review Procedure (DRP))**		Detailed AOR Strategy Development **(Design Review Procedure -Execution Phase)**		AOR Strategy Finalization and update **(DRP)**		AOR and Commissioning Support **(Function Fulfilled)**					
				Strategy Implementation Plan **(PDM and Project Contract, Project Instruction Manual (PIM))**		AOR Strategy Execution **(DRP)**							
						Commissioning Process Development **(Project Commissioning Procedure)**							
				AOR Business driven changes Management Plan Establishment **(Completed during Concept phase: Project Design Manual (PDM) and Project Contract)**		Recording of Project Changes **(Project Change Management Procedure)**		Change Documentation and As-Build Updates **(submission delayed with some documentation submitted post commercialization)**					
				AOR Review Plan Development **(End-of-Phase-Review conducted by Engineering and supporting structures)**				Review AOR Completeness **(Handover Review Report)**					
						RAM Process Establishment and Review **(RAMS completed during definition phase not component specific)**		Plant Optimization and Operation threshold establishment **(Capability Test, Reliability Runs, and Performance contract- delayed)**					
			83%		85%		76%		62%		26.8%	77%	Need Improvement
2	AOR Funding and Budget	Funding and Budget Establishment **(Engineering Project Budget allocated)**		AOR budget Baselining **(Completed through WBS creation)**									
3	Communication Structure	AOR Communication Plan Development **(Project Communication Integrated Management System (CIMS) , Project Contract Documentation)**		Establish Service delivery agreement **(Fulfilled through Secondments agreements between the project and Engineering support department)**									
				Establish Operating Level Agreement **(Secondment agreements)**									
4	Gap Analysis			Gap Reviews Methodology Establishment **(Project Lesson Learnt which were effective on that implementation stage)**		Establishment of GAPs Mitigation Plan **(Partial fulfilled)**		Closure of Punch Items **(Partially fulfilled due to resistance in accountability and decision making)**					
5	Monitoring and Control			AOR Project Scheduling **(Partial effective with no controls on integration due to project delays)**		AOR Project Control Oversight **(Oversight provided but not effective)**		Oversight and Supervision of Commissioning activities **(Partially fulfilled with insufficient proof of involvement)**					

ASSESSMENT REMARKS: AUXILARY BOILER, COAL MILL, BOILER FURNACE, & FABRIC FILTER PLANT
1. The Gap Analysis in a form of lesson learnt for the project has been carried out progressively which delays as it was implemented late in the project with provious failures experinced in successive assets of same design amd magnitude. The mitigation of the gaps identified has been ineffective throughout the project life cycle and this is evident in the RCA conducted in this study showing that some of the instances could have been avoided by acknowledging the challenges faced and ensuring that there are mitigations and those mitigations are implemented correctly and on time.
2. There are defects which have been picked up which have emerged from the construction activities. Some of the defects have not been resolved within the defect periods and this has a major contribution to the availability and reliability of the plant. The maintenance cost is one of the concerns which the client has to deal with as some of the failres are not justifiable during operation and are source of failre to deliver an asset that is sound to operation.
3. Design Review Procedure which can be compared to an asset oprational readiness document or framework is one of the key factor which has major contribution to the reduced percentage of the AOR Readiness core score. This is due to the delays in implementing a comprehensive model to deal with the operational readiness challenges as and when required in the life cycle of the project. There are also concerns in the details of the assessment during multiple review conducted such as end of phase review, Integarted design review, and design freeze. These challenges of detail in the the review stages of gates is evident with the multiple inteface related issues experinces in all the fleet.
4. The RAM Study has been developed but does not provide suffcient details as required in a well-document RAMS which details systems in isolation to arrive at a overall asset RAMS, and this can be seen in the study which covers all the case studies in consideration in this report. Although the RAMS does provide graphical representation, this RAMS has not been updated with the defects and changes made during the course of implementation.
5. The RCA, Surveys and Case Study conducted has revealed that there are issues with the stakeholder engagement to ensure that there is clear business objective when going through all the phases to deliver a sound product, and this can be seen with the lack of knowledge on project related documentation and the expectation from each project participant. There are also issues with the integration of department to have all stakeholders aware of project drives and boundaries. This can also be seen during the execution phase with department assuming roles which are not necessarily included in their mandates.

BOILER PLANT AOR CASE STUDY (AUXILIARY BOILER/ COAL MILL/ BOILER FURNANCE/ FABRIC FILTER PLANT)

Item #	Item Description	AOR Support Planning and Implementation (Weigh 10%)											
		PROPOSED METHOD											
		Conceptual Phase			Definition Phase			Execution/ Implementation phase			Commissioning /Takeover Phase		
1	AOR Manpower	AOR Team Establishment			AOR Team Training and Development AOR Team Roles and Responsibility Definition AOR Team Deployment						AOR and Commissioning Support		
2	Project Resource Support	Software Support System Establishment AOR implementation Tools identification			Definition of Operational Support Plan			Operational Support Plan Implementation					
2	Quality Control and Assurance	Quality Support Requirement											

		NEW BUILD PROJECT METHOD															
		Conceptual Phase			Definition Phase			Execution/ Implementation phase			Commissioning /Takeover Phase			Final Score		
1	AOR Manpower	AOR Team Establishment: **(AOR Function was incorporated in the Engineering Team with delays noted)**	!	75%	AOR Team Training and Development : **(Contractor Skill Transfer Programme)**	✓	83%			67%	AOR and Commissioning Support (Completed partially with certain commissioning activities not have sufficient evidence)	!	67%	7.7%	77%	Need Improvement
					AOR Team Roles and Responsibility Definition **(Roles defined but not integrated)**	!										
					AOR Team Deployment **(executed through secondment to applicable sites, not properly delegated)**	!										
2	Project Resource Support	Software Support System Establishment: **(3D Models with limitation in capabilities)**	!		Definition of Operational Support Plan **(Fulfilled through man-hour planning)**	✓		Operational Support Plan Implementation **(Completed with delays due to project setups)**	!							
		AOR implementation Tools identification: **(defined for all modelling tools and software with limitations)**	!													
3	Quality Control and Assurance	Quality Support Requirement: **(PQM/CQM)**	✓													

ASSESSMENT REMARKS: AUXILARY BOILER, COAL MILL, BOILER FURNACE, & FABRIC FILTER PLANT
1. The Outsourced service for Project Management and AOR was not executed to the required standards and has led to challenges which are considered to be legacy issues of the projects cause a major upset to the delivery time of the project. This has also led to delays and issues with the documentation required for handover of the asset.
2. There are software and tools requirement for detailed assessment of provided design which have also contributed to failure to perform detailed reviews during review gates of the PLCM. The limitation with the tools entails that the assessment are conducted at a high-level for the purpose of initiating the execution stage of the project and this increases the risk associated with the assessed equipment.
3. Although this are has a relatively high rating in comparison to the some of the assessment categories, AOR team roles and responsibility remains one of the major key element which needs improvement. The Roles and reponsibilities challenges emanate from the failure to clearly define the boundaries in the initial stage of the project when in come to design engineering and AOR Roles and responsibilities. This was also identified by the management when later there was a drive to define the role of an engineer on the field to distiguish a role of a design engineer.

19. APPENDIX C: QUALITATIVE SURVEYS

1ST INTERVIEWEE SURVEY WITH RESPONSE						
			Interviewee Answers			
Item Number	Type	Questions	Short Answer (Yes/No)	Comments	Suggestion (Improvement)	Score
1	GENERAL	Is Asset Operational Readiness (AOR) plan or strategy (If any) well defined in the orgnanization?	Yes	The Project has developed the Handover Review (HDRR) process in place		50%
2		Is AOR a separate department with all necessary process and procedure?	No	HDRR are done by the same Engineering Department for which it is a problem since Engineers has a lot to deal with and this is additonal scope of work and it makes it very difficult to escalte it and finish on time.	A specific task team to be assigned to make this efffective	
3		AOR budget clearly defined by the business for pre-feasibility phase to handover phase (PLCM)?	Partially Fulfilled	As part of the project, you start the project until the execution		
1	EQUIPMENT AND DOCUMENTATION READINESS	Are all the Regulatory and compliance requirements for all the newbuild systems and equipment fulfilled?	Yes			91%
2		Are the systems/equipment delivered in line with the operational requirements?	Partially Fulfilled	Some equipment are delivered accordingly or as per the spec but some come defected due to handling and thoroughly inspections are required.		
3		Is the Engineering and Quality Process implemented accordingly to Achieve system clearance and Registration?	Yes	Engineers always make sure that the works are as per the design and quaility is achieved		
4		Has the business ensured that spare equipment, or maintenance and operational services required during operation are factored into the Life cycle model?	Yes	Spares as per the Contract are in place but there are spare that the Client (Gx) needs to	Client to make sure that Spares Contract is placed on time	
5		Is the O&M documentation made available during commissioning or operation of the asset?	Yes	The documents are made availble before Commissioning of the plant		
6		Is the Electrical and C&I infrastructure/design adequately integrated to the mechanical equipment prior to commercialization of the asset?	Yes			
7		Is there a defined process for equipment re-location (swap) during construction?	Yes	if it happens that the project needs to swap some material across the units, the "Swap Form" is signed or made avaialable		
8		Is the Specification (Employer's Contract) adequately detail to eliminate ambiguity?	Yes	The project is governed by a signed contract		
9		Is the Intergrated Design Review Report sufficient for ensuring harmony between various stakeholder or interface?	Yes	All IDR were approved before the start of the works on site.		
10		Is the Pre-Commissioning Review Report "details" adequate for readiness of the equipment to be commissioned in a safe manner?	Partially Fulfilled	PCRs checklists are signed off before each commisioning phase commences	PCR documents/reports need to in place prior commisioning. Currently only PCR Checklists are signed off.	
11		Is the Handover Design Review Report (Matrix) a good tool to verify the readiness of the plant for the client to operate?	Yes	HDRR is a very good tool that is being used in providing all the necessary documentation that is required to operate the plant. It makes it easier to get the required documents on SPO and fast track the seraching		
12		Is the Engineering Change Process, Risk Assessment, and Non-conformance Management well documented throughout the PLCM?	Yes	There are registers in plce to capture all the ECNs, RA and NCR for the changes made or discrabances		
13		Are all the Design Documents submitted on time with As-Build Information for Operation and Maintenance (O&M)?	Partially Fulfilled	Not all documents are submitted. As built information will only be submitted with final documentation as the Contractor cannot submit such		
14		Does the project have detailed RAM (Reliability, Availability, Maintenability) Studies and is there a need to produce detailed RAMS for all the system?	Yes	RAM study is in place		
15		Bill of Materials documentation adequate to guide the O&M team on maintenability of the Power Plant?	Yes			
16		Is there sufficient Documentation for Procurement Spare Parts during Maintenance of the Plant	Yes	F2 spare list has been popolated to cater for procurement of spare for Gx		
17		Is the Spare Parts Documentation submitted prior to Operation	Yes	F1 and F2 spare in place		
1	COMPETENCY READINESS	Is the business aware of the importance of AOR to ensure that there are right skill-sets and competencies?	Yes			50%
2		Is there a programme to develop the staff identified for Plant Operation prior to Plant takeover?	Yes			
3		Does the business have a Methods to profile and assess the competency of each individual as they develop?	Partially Fulfilled	This is not fully mamaged. It depends on mamger's preferences.		
4		Is the AOR team (if any) established at the right phase of the PLCM (Project Life Cycle Model) with well defined Roles and Responsibilities?	No	Never heard of any team	Team to be developed	
5		Is there continuous improvement of individual skills to effectively outline and perform tasks and activities pertaining to AOR?	No			
1	OTHER	Is the AOR Process (If any) complimenting the delivery of the project?	No			0%
2		Is there an escalation process for AOR related concerns which has not been addressed during the PLCM (if AOR exist)?	No			

2ND INTERVIEWEE SURVEY WITH RESPONSE						
			Interviewee Answers			
Item Number	Type	Questions	Short Answer (Yes/No)	Comments	Suggestion (Improvement)	Score
1	GENERAL	Is Asset Operational Readiness (AOR) plan or strategy (If any) well defined in the orgnanization?	Partially Fulfilled	the current method is to use to knowledge that was gained from operating/old plants. The learnings are well documented in Eskom standards/guidelines		33%
2		Is AOR a separate department with all necessary process and procedure?	No	consist of multi desciplinary team		
3		AOR budget clearly defined by the business for pre-feasibility phase to handover phase (PLCM)?	Partially Fulfilled	through different call centres		
1	EQUIPMENT AND DOCUMENTATION READINESS	Are all the Regulatory and compliance requirements for all the newbuild systems and equipment fulfilled?	Yes	This is fullfilled to fullfilled on equipment that falls witthin		84%
2		Are the systems/equipment delivered in line with the operational requirements?	Yes			
3		Is the Engineering and Quality Process implemented accordingly to Achieve system clearance and Registration?	Yes			
4		Has the business ensured that spare equipment, or maintenance and operational services required during operation are factored into the Life cycle model?	Yes	Spare equipment is not fully factored		
5		Is the O&M documentation made available during commissioning or operation of the asset?	Yes	Handover of all documentation is not yet finalised but most are available for the end user		
6		Is the Electrical and C&I infrastructure/design adequately integrated to the mechanical equipment prior to commercialization of the asset?	Not Applicable	To my knowledge it is, but an informed feedback can be obtained from the C&I and commisioning team		
7		Is there a defined process for equipment re-location (swap) during construction?	Partially Fulfilled	The process is not clearly defined although there was an existing swapping register during fabrication and yet to obtain a swapping register from construction/site		
8		Is the Specification (Employer's Contract) adequately detail to eliminate ambiguity?	Yes	for pressure parts and boiler structure		
9		Is the Intergrated Design Review Report sufficient for ensuring harmony between various stakeholder or interface?	Yes			
10		Is the Pre-Commissioning Review Report "details" adequate for readiness of the equipment to be commissioned in a safe manner?	Yes			
11		Is the Handover Design Review Report (Matrix) a good tool to verify the readiness of the plant for the client to operate?	Yes			
12		Is the Engineering Change Process, Risk Assessment, and Non-conformance Management well documented throughout the PLCM?	Yes	for pressure parts and boiler structure (not aware for turbine and other systems)		
13		Are all the Design Documents submitted on time with As-Build Information for Operation and Maintenance (O&M)?	No			
14		Does the project have detailed RAM (Reliability, Availability, Maintenability) Studies and is there a need to produce detailed RAMS for all the system?	Partially Fulfilled	There need to studies on the systems where there notable design flaws i.e. to ensure that the plant is operated optimaly		
15		Bill of Materials documentation adequate to guide the O&M team on maintenability of the Power Plant?	Yes	for pressure parts and boiler structure (not aware for turbine and other systems)		
16		Is there sufficient Documentation for Procurement Spare Parts during Maintenance of the Plant	Yes	detailed information (e.g. drawings etc.) not available for off the shelf equipment		
17		Is the Spare Parts Documentation submitted prior to Operation	Partially Fulfilled	Some spare parts were used during construction and replaced after the the unit(s) have operated		
1	COMPETENCY READINESS	Is the business aware of the importance of AOR to ensure that there are right skill-sets and competencies?	Partially Fulfilled	Although not a regid structure, there team consist of different role players, ensuring that that the asset is ready for operation		50%
2		Is there a programme to develop the staff identified for Plant Operation prior to Plant takeover?	Partially Fulfilled	Not aware of the programme		
3		Does the business have a Methods to profile and assess the competency of each individual as they develop?	Partially Fulfilled	not a well defined method		
4		Is the AOR team (if any) established at the right phase of the PLCM (Project Life Cycle Model) with well defined Roles and Responsibilities?	Partially Fulfilled	some resources were placed at the sub-contractors facilities to ensure that assets are ready for operation		
5		Is there continuous improvement of individual skills to effectively outline and perform tasks and activities pertaining to AOR?	Partially Fulfilled	through attendance of workshops and internal/external training. This is not extensive due to cost cutting		
1	OTHER	Is the AOR Process (If any) complimenting the delivery of the project?	Yes			75%
2		Is there an escalation process for AOR related concerns which has not been addressed during the PLCM (if AOR exist)?	Partially Fulfilled			

3RD INTERVIEWEE SURVEY WITH RESPONSE						
			Interviewee Answers			
Item Number	Type	Questions	Short Answer (Yes/No)	Comments	Suggestion (Improvement)	
	GENERAL					
1		Is Asset Operational Readiness (AOR) plan or strategy (If any) well defined in the orgnanization?	No			0%
2		Is AOR a separate department with all necessary process and procedure?	No			
3		AOR budget clearly defined by the business for pre-feasibility phase to handover phase (PLCM)?	No			
1	EQUIPMENT AND DOCUMENTATION READINESS	Are all the Regulatory and compliance requirements for all the newbuild systems and equipment fulfilled?	Yes			62%
2		Are the systems/equipment delivered in line with the operational requirements?	Partially Fulfilled			
3		Is the Engineering and Quality Process implemented accordingly to Achieve system clearance and Registration?	Yes			
4		Has the business ensured that spare equipment, or maintenance and operational services required during operation are factored into the Life cycle model?	Yes			
5		Is the O&M documentation made available during commissioning or operation of the asset?	Yes			
6		Is the Electrical and C&I infrastructure/design adequately integrated to the mechanical equipment prior to commercialization of the asset?	Yes	Through plant optimisation		
7		Is there a defined process for equipment re-location (swap) during construction?	No			
8		Is the Specification (Employer's Contract) adequately detail to eliminate ambiguity?	Partially Fulfilled			
9		Is the Intergrated Design Review Report sufficient for ensuring harmony between various stakeholder or interface?	Partially Fulfilled	Partially because Environmental sometimes is not involved		
10		Is the Pre-Commissioning Review Report "details" adequate for readiness of the equipment to be commissioned in a safe manner?	Yes			
11		Is the Handover Design Review Report (Matrix) a good tool to verify the readiness of the plant for the client to operate?	No			
12		Is the Engineering Change Process, Risk Assessment, and Non-conformance Management well documented throughout the PLCM?	Partially Fulfilled			
13		Are all the Design Documents submitted on time with As-Build Information for Operation and Maintenance (O&M)?	No			
14		Does the project have detailed RAM (Reliability, Availability, Maintenability) Studies and is there a need to produce detailed RAMS for all the system?	Yes			
15		Bill of Materials documentation adequate to guide the O&M team on maintenability of the Power Plant?	No			
16		Is there sufficient Documentation for Procurement Spare Parts during Maintenance of the Plant	Yes	GM03s		
17		Is the Spare Parts Documentation submitted prior to Operation	Partially Fulfilled			
1	COMPETENCY READINESS	Is the business aware of the importance of AOR to ensure that there are right skill-sets and competencies?	Partially Fulfilled			20%
2		Is there a programme to develop the staff identified for Plant Operation prior to Plant takeover?	Partially Fulfilled			
3		Does the business have a Methods to profile and assess the competency of each individual as they develop?	No			
4		Is the AOR team (if any) established at the right phase of the PLCM (Project Life Cycle Model) with well defined Roles and Responsibilities?	No			
5		Is there continuous improvement of individual skills to effectively outline and perform tasks and activities pertaining to AOR?	No			
1	OTHER	Is the AOR Process (If any) complimenting the delivery of the project?	No			0%
2		Is there an escalation process for AOR related concerns which has not been addressed during the PLCM (if AOR exist)?	No			

4TH INTERVIEWEE SURVEY WITH RESPONSE						
			Interviewee Answers			
Item Number	Type	Questions	Short Answer (Yes/No)	Comments	Suggestion (Improvement)	
1	GENERAL	Is Asset Operational Readiness (AOR) plan or strategy (If any) well defined in the orgnanization?	Yes			
2		Is AOR a separate department with all necessary process and procedure?	Yes			100%
3		AOR budget clearly defined by the business for pre-feasibility phase to handover phase (PLCM)?	Yes			
1	EQUIPMENT AND DOCUMENTATION READINESS	Are all the Regulatory and compliance requirements for all the newbuild systems and equipment fulfilled?	Yes			
2		Are the systems/equipment delivered in line with the operational requirements?	Yes			
3		Is the Engineering and Quality Process implemented accordingly to Achieve system clearance and Registration?	Yes			
4		Has the business ensured that spare equipment, or maintenance and operational services required during operation are factored into the Life cycle model?	Partially Fulfilled			
5		Is the O&M documentation made available during commissioning or operation of the asset?	Yes			
6		Is the Electrical and C&I infrastructure/design adequately integrated to the mechanical equipment prior to commercialization of the asset?	Yes			
7		Is there a defined process for equipment re-location (swap) during construction?	Yes			
8		Is the Specification (Employer's Contract) adequately detail to eliminate ambiguity?	Yes			
9		Is the Intergrated Design Review Report sufficient for ensuring harmony between various stakeholder or interface?	Partially Fulfilled			
10		Is the Pre-Commissioning Review Report "details" adequate for readiness of the equipment to be commissioned in a safe manner?	Yes			
11		Is the Handover Design Review Report (Matrix) a good tool to verify the readiness of the plant for the client to operate?	Yes			82%
12		Is the Engineering Change Process, Risk Assessment, and Non-conformance Management well documented throughout the PLCM?	Yes			
13		Are all the Design Documents submitted on time with As-Build Information for Operation and Maintenance (O&M)?	No	we still continue without the red lined drawing in most areas		
14		Does the project have detailed RAM (Reliability, Availability, Maintenability) Studies and is there a need to produce detailed RAMS for all the system?	Yes			
15		Bill of Materials documentation adequate to guide the O&M team on maintenability of the Power Plant?	Yes			
16		Is there sufficient Documentation for Procurement Spare Parts during Maintenance of the Plant	Yes			
17		Is the Spare Parts Documentation submitted prior to Operation	No	so far there are no spares		
1	COMPETENCY READINESS	Is the business aware of the importance of AOR to ensure that there are right skill-sets and competencies?	Yes			
2		Is there a programme to develop the staff identified for Plant Operation prior to Plant takeover?	Yes			
3		Does the business have a Methods to profile and assess the competency of each individual as they develop?	Partially Fulfilled			80%
4		Is the AOR team (if any) established at the right phase of the PLCM (Project Life Cycle Model) with well defined Roles and Responsibilities?	Partially Fulfilled			
5		Is there continuous improvement of individual skills to effectively outline and perform tasks and activities pertaining to AOR?	Yes			
1	OTHER	Is the AOR Process (If any) complimenting the delivery of the project?	Yes			
2		Is there an escalation process for AOR related concerns which has not been addressed during the PLCM (if AOR exist)?	Yes	continuous improvement is necessary		100%

5TH INTERVIEWEE SURVEY WITH RESPONSE						
			Interviewee Answers			
Item Number	Type	Questions	Short Answer (Yes/No)	Comments	Suggestion (Improvement)	
	GENERAL					
1		Is Asset Operational Readiness (AOR) plan or strategy (If any) well defined in the orgnanization?	Partially Fulfilled	The organization does have a plan but has gaps that were identified and are corrected as the AOR is prepared		25%
2		Is AOR a separate department with all necessary process and procedure?	No	It is lead by the joint Engineering/Commissioning Departments but it integrates all other relevent departments		
3		AOR budget clearly defined by the business for pre-feasibility phase to handover phase (PLCM)?	Not Applicable	This is outside our scope.		
1	EQUIPMENT AND DOCUMENTATION READINESS	Are all the Regulatory and compliance requirements for all the newbuild systems and equipment fulfilled?	Yes	WULA,EIA,AIA, Compliance OSHAS.		77%
2		Are the systems/equipment delivered in line with the operational requirements?	Partially Fulfilled	Some of the equipment were delivered without the necessary documentation. This was not clear to both initially to both the employer and the contractor.		
3		Is the Engineering and Quality Process implemented accordingly to Achieve system clearance and Registration?	Yes	Althought it was not a perfect system		
4		Has the business ensured that spare equipment, or maintenance and operational services required during operation are factored into the Life cycle model?	Not Applicable	The Project is the execution phase,which is managed by a different business Unit. On		
5		Is the O&M documentation made available during commissioning or operation of the asset?	Yes	O&M Manual are critical documentation for Assert takeover		
6		Is the Electrical and C&I infrastructure/design adequately integrated to the mechanical equipment prior to commercialization of the asset?	Yes	Intergration of this disciplines is tested and confirmed during commissioning phase prior commercialization		
7		Is there a defined process for equipment re-location (swap) during construction?	Yes	The is a defined process however it might NOT have been followed to the tee by everybody.		
8		Is the Specification (Employer's Contract) adequately detail to eliminate ambiguity?	No	In Mega Project this is expected but to the minimum.		
9		Is the Intergrated Design Review Report sufficient for ensuring harmony between various stakeholder or interface?	Yes			
10		Is the Pre-Commissioning Review Report "details" adequate for readiness of the equipment to be commissioned in a safe manner?	Yes	The process is in place "Construction Turn Over" supplemented by Plant Walk Down to ensure safety and completion.		
11		Is the Handover Design Review Report (Matrix) a good tool to verify the readiness of the plant for the client to operate?	Yes			
12		Is the Engineering Change Process, Risk Assessment, and Non-conformance Management well documented throughout the PLCM?	Yes			
13		Are all the Design Documents submitted on time with As-Build Information for Operation and Maintenance (O&M)?	Yes			
14		Does the project have detailed RAM (Reliability, Availability, Maintenability) Studies and is there a need to produce detailed RAMS for all the system?	No	I am not aware of this and therefore can not comment.		
15		Bill of Materials documentation adequate to guide the O&M team on maintenability of the Power Plant?	No			
16		Is there sufficient Documentation for Procurement Spare Parts during Maintenance of the Plant	Not Applicable	This will be the responsibility of the Operating Business Units		
17		Is the Spare Parts Documentation submitted prior to Operation	Yes	Is part of the contract with contractor		
1	COMPETENCY READINESS	Is the business aware of the importance of AOR to ensure that there are right skill-sets and competencies?	Yes	Hence Training by the suppliers of the Assert is part of the contract.		67%
2		Is there a programme to develop the staff identified for Plant Operation prior to Plant takeover?	Yes	The training programme started long before the completion of the Assert creation.		
3		Does the business have a Methods to profile and assess the competency of each individual as they develop?	Not Applicable	I am not aware of this and therefore can not comment.		
4		Is the AOR team (if any) established at the right phase of the PLCM (Project Life Cycle Model) with well defined Roles and Responsibilities?	Not Applicable	I am not aware of this and therefore can not comment.		
5		Is there continuous improvement of individual skills to effectively outline and perform tasks and activities pertaining to AOR?	No	I am not aware of this and I have never heared of.		
1	OTHER	Is the AOR Process (If any) complimenting the delivery of the project?	No	If any I am not aware of.		0%
2		Is there an escalation process for AOR related concerns which has not been addressed during the PLCM (if AOR exist)?	No	If any I am not aware of.		

6TH INTERVIEWEE SURVEY WITH RESPONSE						
			Interviewee Answers			
Item Number	Type	Questions	Short Answer (Yes/No)	Comments	Suggestion (Improvement)	
	GENERAL					
1		Is Asset Operational Readiness (AOR) plan or strategy (If any) well defined in the orgnanization?	Yes	On all our three(3) major BU's we hve completant resources		67%
2		Is AOR a separate department with all necessary process and procedure?	Yes	No comment	Each BU should have its own department for AOR	
3		AOR budget clearly defined by the business for pre-feasibility phase to handover phase (PLCM)?	No	rate of failure of our assets says it all	Dedicated resources to manage the assest could be great	
1	EQUIPMENT AND DOCUMENTATION READINESS	Are all the Regulatory and compliance requirements for all the newbuild systems and equipment fulfilled?	Yes	no comment		94%
2		Are the systems/equipment delivered in line with the operational requirements?	Yes	no comment		
3		Is the Engineering and Quality Process implemented accordingly to Achieve system clearance and Registration?	Yes	But not at all times, sometimes we slip	Continual Improvement, and assessment of the team	
4		Has the business ensured that spare equipment, or maintenance and operational services required during operation are factored into the Life cycle model?	Yes	no comment		
5		Is the O&M documentation made available during commissioning or operation of the asset?	Yes	Not always,		
6		Is the Electrical and C&I infrastructure/design adequately integrated to the mechanical equipment prior to commercialization of the asset?	Yes	no comment		
7		Is there a defined process for equipment re-location (swap) during construction?	Yes	no comment		
8		Is the Specification (Employer's Contract) adequately detail to eliminate ambiguity?	No	This is area the business fails all the time		
9		Is the Intergrated Design Review Report sufficient for ensuring harmony between various stakeholder or interface?	Yes			
10		Is the Pre-Commissioning Review Report "details" adequate for readiness of the equipment to be commissioned in a safe manner?	Yes	But not sure	I think if Commissioning may be included within Engineering we may have a different picture	
11		Is the Handover Design Review Report (Matrix) a good tool to verify the readiness of the plant for the client to operate?	Yes			
12		Is the Engineering Change Process, Risk Assessment, and Non-conformance Management well documented throughout the PLCM?	Yes			
13		Are all the Design Documents submitted on time with As-Build Information for Operation and Maintenance (O&M)?	Yes			
14		Does the project have detailed RAM (Reliability, Availability, Maintenability) Studies and is there a need to produce detailed RAMS for all the system?	Yes			
15		Bill of Materials documentation adequate to guide the O&M team on maintenability of the Power Plant?	Yes			
16		Is there sufficient Documentation for Procurement Spare Parts during Maintenance of the Plant	Yes			
17		Is the Spare Parts Documentation submitted prior to Operation	Yes			
1	COMPETENCY READINESS	Is the business aware of the importance of AOR to ensure that there are right skill-sets and competencies?	Yes			100%
2		Is there a programme to develop the staff identified for Plant Operation prior to Plant takeover?	Yes			
3		Does the business have a Methods to profile and assess the competency of each individual as they develop?	Yes			
4		Is the AOR team (if any) established at the right phase of the PLCM (Project Life Cycle Model) with well defined Roles and Responsibilities?	Yes			
5		Is there continuous improvement of individual skills to effectively outline and perform tasks and activities pertaining to AOR?	Yes	Not sure		
1	OTHER	Is the AOR Process (If any) complimenting the delivery of the project?	Yes			100%
2		Is there an escalation process for AOR related concerns which has not been addressed during the PLCM (if AOR exist)?	Yes			

7TH INTERVIEWEE SURVEY WITH RESPONSE						
			Interviewee Answers			
Item Number	Type	Questions	Short Answer (Yes/No)	Comments	Suggestion (Improvement)	
1	GENERAL	Is Asset Operational Readiness (AOR) plan or strategy (If any) well defined in the orgnanization?	No	the current method is to use to knowledge that was gained from operating/old plants. The learnings are well documented in Eskom standards/guidelines		0%
2		Is AOR a separate department with all necessary process and procedure?	No	consist of multi desciplinary team		
3		AOR budget clearly defined by the business for pre-feasibility phase to handover phase (PLCM)?	No	through different call centres		
1	EQUIPMENT AND DOCUMENTATION READINESS	Are all the Regulatory and compliance requirements for all the newbuild systems and equipment fulfilled?	Yes	This is fullfilled to fullfilled on equipment that falls witthin		65%
2		Are the systems/equipment delivered in line with the operational requirements?	Yes			
3		Is the Engineering and Quality Process implemented accordingly to Achieve system clearance and Registration?	Yes			
4		Has the business ensured that spare equipment, or maintenance and operational services required during operation are factored into the Life cycle model?	Yes	Spare equipment is not fully factored		
5		Is the O&M documentation made available during commissioning or operation of the asset?	Yes	Handover of all documentation is not yet finalised but most are available for the end user		
6		Is the Electrical and C&I infrastructure/design adequately integrated to the mechanical equipment prior to commercialization of the asset?	Yes	To my knowledge it is, but an informed feedback can be obtained from the C&I and commisioning team		
7		Is there a defined process for equipment re-location (swap) during construction?	No	The process is not clearly defined although there was an existing swapping register during fabrication and yet to obtain a swapping register from construction/site		
8		Is the Specification (Employer's Contract) adequately detail to eliminate ambiguity?	No	for pressure parts and boiler structure		
9		Is the Intergrated Design Review Report sufficient for ensuring harmony between various stakeholder or interface?	Partially Fulfilled			
10		Is the Pre-Commissioning Review Report "details" adequate for readiness of the equipment to be commissioned in a safe manner?	Partially Fulfilled			
11		Is the Handover Design Review Report (Matrix) a good tool to verify the readiness of the plant for the client to operate?	Partially Fulfilled			
12		Is the Engineering Change Process, Risk Assessment, and Non-conformance Management well documented throughout the PLCM?	Yes	for pressure parts and boiler structure (not aware for turbine and other systems)		
13		Are all the Design Documents submitted on time with As-Build Information for Operation and Maintenance (O&M)?	No			
14		Does the project have detailed RAM (Reliability, Availability, Maintenability) Studies and is there a need to produce detailed RAMS for all the system?	Yes	There need to studies on the systems where there notable design flaws i.e. to ensure that the plant is operated optimaly		
15		Bill of Materials documentation adequate to guide the O&M team on maintenability of the Power Plant?	Yes	for pressure parts and boiler structure (not aware for turbine and other systems)		
16		Is there sufficient Documentation for Procurement Spare Parts during Maintenance of the Plant	Partially Fulfilled	detailed information (e.g. drawings etc.) not available for off the shelf equipment		
17		Is the Spare Parts Documentation submitted prior to Operation	No	Some spare parts were used during construction and replaced after the the unit(s) have operated		
1	COMPETENCY READINESS	Is the business aware of the importance of AOR to ensure that there are right skill-sets and competencies?	No	Although not a regid structure, there team consist of different role players, ensuring that that the asset is ready for operation		10%
2		Is there a programme to develop the staff identified for Plant Operation prior to Plant takeover?	Partially Fulfilled	Not aware of the programme		
3		Does the business have a Methods to profile and assess the competency of each individual as they develop?	No	not a well defined method		
4		Is the AOR team (if any) established at the right phase of the PLCM (Project Life Cycle Model) with well defined Roles and Responsibilities?	No	some resources were placed at the sub-contractors facilities to ensure that assets are ready for operation		
5		Is there continuous improvement of individual skills to effectively outline and perform tasks and activities pertaining to AOR?	No	through attendance of workshops and internal/external training. This is not extensive due to cost cutting		
1	OTHER	Is the AOR Process (If any) complimenting the delivery of the project?	No			0%
2		Is there an escalation process for AOR related concerns which has not been addressed during the PLCM (if AOR exist)?	No			

8TH INTERVIEWEE SURVEY WITH RESPONSE						
			Interviewee Answers			
Item Number	Type	Questions	Short Answer (Yes/No)	Comments	Suggestion (Improvement)	
	GENERAL					
1		Is Asset Operational Readiness (AOR) plan or strategy (If any) well defined in the orgnanization?	Partially Fulfilled	Most likely to be part of corporate plan		17%
2		Is AOR a separate department with all necessary process and procedure?	No	I think it needs to be a BU as oppose to a department		
3		AOR budget clearly defined by the business for pre-feasibility phase to handover phase (PLCM)?	No			
1	EQUIPMENT AND DOCUMENTATION READINESS	Are all the Regulatory and compliance requirements for all the newbuild systems and equipment fulfilled?	Partially Fulfilled	International experts employed for new build did		65%
2		Are the systems/equipment delivered in line with the operational requirements?	Partially Fulfilled	There are no documented systems and therfore product quality is compromised in the absence of systems		
3		Is the Engineering and Quality Process implemented accordingly to Achieve system clearance and Registration?	No	quality processes are not accredited to credible certification bodies		
4		Has the business ensured that spare equipment, or maintenance and operational services required during operation are factored into the Life cycle model?	Yes	But Eskom lack the capacity to operate and maitain the plant		
5		Is the O&M documentation made available during commissioning or operation of the asset?	Yes	There is no traceability and identification of commissioning documents and cerficated		
6		Is the Electrical and C&I infrastructure/design adequately integrated to the mechanical equipment prior to commercialization of the asset?	Partially Fulfilled	Interfaces between electrical and mechanica are not clearly defined.		
7		Is there a defined process for equipment re-location (swap) during construction?	Partially Fulfilled	Some equipment are dispached to site without proper documentation		
8		Is the Specification (Employer's Contract) adequately detail to eliminate ambiguity?	No	Some construction were undertaken without following the latest revision specification		
9		Is the Intergrated Design Review Report sufficient for ensuring harmony between various stakeholder or interface?	Yes			
10		Is the Pre-Commissioning Review Report "details" adequate for readiness of the equipment to be commissioned in a safe manner?	Yes			
11		Is the Handover Design Review Report (Matrix) a good tool to verify the readiness of the plant for the client to operate?	Yes			
12		Is the Engineering Change Process, Risk Assessment, and Non-conformance Management well documented throughout the PLCM?	No	Non conformances are not properly streamlined		
13		Are all the Design Documents submitted on time with As-Build Information for Operation and Maintenance (O&M)?	Partially Fulfilled	Defects are as a result of not building as per design		
14		Does the project have detailed RAM (Reliability, Availability, Maintenability) Studies and is there a need to produce detailed RAMS for all the system?	Yes			
15		Bill of Materials documentation adequate to guide the O&M team on maintenability of the Power Plant?	Yes			
16		Is there sufficient Documentation for Procurement Spare Parts during Maintenance of the Plant	Partially Fulfilled	Due to lack of proper contracting strategy		
17		Is the Spare Parts Documentation submitted prior to Operation	Yes			
1	COMPETENCY READINESS	Is the business aware of the importance of AOR to ensure that there are right skill-sets and competencies?	Yes			20%
2		Is there a programme to develop the staff identified for Plant Operation prior to Plant takeover?	Yes			
3		Does the business have a Methods to profile and assess the competency of each individual as they develop?	Yes	We reactive in that approach. Only at the tail end that we doing well. But planning side is lacking		
4		Is the AOR team (if any) established at the right phase of the PLCM (Project Life Cycle Model) with well defined Roles and Responsibilities?	Yes			
5		Is there continuous improvement of individual skills to effectively outline and perform tasks and activities pertaining to AOR?	Not Applicable			
1	OTHER	Is the AOR Process (If any) complimenting the delivery of the project?	Not Applicable			50%
2		Is there an escalation process for AOR related concerns which has not been addressed during the PLCM (if AOR exist)?	Yes			

9TH INTERVIEWEE SURVEY WITH RESPONSE						
			Interviewee Answers			
Item Number	Type	Questions	Short Answer (Yes/No)	Comments	Suggestion (Improvement)	
1	GENERAL	Is Asset Operational Readiness (AOR) plan or strategy (If any) well defined in the orgnanization?	No			0%
2		Is AOR a separate department with all necessary process and procedure?	No			
3		AOR budget clearly defined by the business for pre-feasibility phase to handover phase (PLCM)?	No			
1	EQUIPMENT AND DOCUMENTATION READINESS	Are all the Regulatory and compliance requirements for all the newbuild systems and equipment fulfilled?	Yes			78%
2		Are the systems/equipment delivered in line with the operational requirements?	Yes			
3		Is the Engineering and Quality Process implemented accordingly to Achieve system clearance and Registration?	Yes			
4		Has the business ensured that spare equipment, or maintenance and operational services required during operation are factored into the Life cycle model?	Yes			
5		Is the O&M documentation made available during commissioning or operation of the asset?	Yes			
6		Is the Electrical and C&I infrastructure/design adequately integrated to the mechanical equipment prior to commercialization of the asset?	Not Applicable			
7		Is there a defined process for equipment re-location (swap) during construction?	No			
8		Is the Specification (Employer's Contract) adequately detail to eliminate ambiguity?	No			
9		Is the Intergrated Design Review Report sufficient for ensuring harmony between various stakeholder or interface?	Yes			
10		Is the Pre-Commissioning Review Report "details" adequate for readiness of the equipment to be commissioned in a safe manner?	Yes			
11		Is the Handover Design Review Report (Matrix) a good tool to verify the readiness of the plant for the client to operate?	Yes			
12		Is the Engineering Change Process, Risk Assessment, and Non-conformance Management well documented throughout the PLCM?	Yes			
13		Are all the Design Documents submitted on time with As-Build Information for Operation and Maintenance (O&M)?	Partially Fulfilled			
14		Does the project have detailed RAM (Reliability, Availability, Maintenability) Studies and is there a need to produce detailed RAMS for all the system?	Yes			
15		Bill of Materials documentation adequate to guide the O&M team on maintenability of the Power Plant?	No			
16		Is there sufficient Documentation for Procurement Spare Parts during Maintenance of the Plant	Yes			
17		Is the Spare Parts Documentation submitted prior to Operation	Yes			
1	COMPETENCY READINESS	Is the business aware of the importance of AOR to ensure that there are right skill-sets and competencies?	Yes			20%
2		Is there a programme to develop the staff identified for Plant Operation prior to Plant takeover?	No			
3		Does the business have a Methods to profile and assess the competency of each individual as they develop?	No			
4		Is the AOR team (if any) established at the right phase of the PLCM (Project Life Cycle Model) with well defined Roles and Responsibilities?	No			
5		Is there continuous improvement of individual skills to effectively outline and perform tasks and activities pertaining to AOR?	No			
1	OTHER	Is the AOR Process (If any) complimenting the delivery of the project?	Yes			50%
2		Is there an escalation process for AOR related concerns which has not been addressed during the PLCM (if AOR exist)?	No			

10TH INTERVIEWEE SURVEY WITH RESPONSE						
			Interviewee Answers			
Item Number	Type	Questions	Short Answer (Yes/No)	Comments	Suggestion (Improvement)	
	GENERAL					
1		Is Asset Operational Readiness (AOR) plan or strategy (If any) well defined in the orgnanization?	No			0%
2		Is AOR a separate department with all necessary process and procedure?	No			
3		AOR budget clearly defined by the business for pre-feasibility phase to handover phase (PLCM)?	No			
1	EQUIPMENT AND DOCUMENTATION READINESS	Are all the Regulatory and compliance requirements for all the newbuild systems and equipment fulfilled?	Yes			71%
2		Are the systems/equipment delivered in line with the operational requirements?	Yes			
3		Is the Engineering and Quality Process implemented accordingly to Achieve system clearance and Registration?	Yes	The responsible engineer need to give clearance as part of the process		
4		Has the business ensured that spare equipment, or maintenance and operational services required during operation are factored into the Life cycle model?	Partially Fulfilled	There are spares ordered for commisioning phase that will be handed over to Gx if		
5		Is the O&M documentation made available during commissioning or operation of the asset?	Yes			
6		Is the Electrical and C&I infrastructure/design adequately integrated to the mechanical equipment prior to commercialization of the asset?	Yes			
7		Is there a defined process for equipment re-location (swap) during construction?	Yes			
8		Is the Specification (Employer's Contract) adequately detail to eliminate ambiguity?	Partially Fulfilled	Not always. Some requirements are open for interpretation.		
9		Is the Intergrated Design Review Report sufficient for ensuring harmony between various stakeholder or interface?	No	Changes during contruction is not covered in the IDR.		
10		Is the Pre-Commissioning Review Report "details" adequate for readiness of the equipment to be commissioned in a safe manner?	Yes			
11		Is the Handover Design Review Report (Matrix) a good tool to verify the readiness of the plant for the client to operate?	No			
12		Is the Engineering Change Process, Risk Assessment, and Non-conformance Management well documented throughout the PLCM?	Yes			
13		Are all the Design Documents submitted on time with As-Build Information for Operation and Maintenance (O&M)?	No			
14		Does the project have detailed RAM (Reliability, Availability, Maintenability) Studies and is there a need to produce detailed RAMS for all the system?	No	Not sure		
15		Bill of Materials documentation adequate to guide the O&M team on maintenability of the Power Plant?	Yes			
16		Is there sufficient Documentation for Procurement Spare Parts during Maintenance of the Plant	Yes			
17		Is the Spare Parts Documentation submitted prior to Operation	Yes			
1	COMPETENCY READINESS	Is the business aware of the importance of AOR to ensure that there are right skill-sets and competencies?	No			0%
2		Is there a programme to develop the staff identified for Plant Operation prior to Plant takeover?	No			
3		Does the business have a Methods to profile and assess the competency of each individual as they develop?	No			
4		Is the AOR team (if any) established at the right phase of the PLCM (Project Life Cycle Model) with well defined Roles and Responsibilities?	No			
5		Is there continuous improvement of individual skills to effectively outline and perform tasks and activities pertaining to AOR?	No			
1	OTHER	Is the AOR Process (If any) complimenting the delivery of the project?	No			0%
2		Is there an escalation process for AOR related concerns which has not been addressed during the PLCM (if AOR exist)?	Not Applicable			

11TH INTERVIEWEE SURVEY WITH RESPONSE						
			Interviewee Answers			
Item Number	Type	Questions	Short Answer (Yes/No)	Comments	Suggestion (Improvement)	
	GENERAL					
1		Is Asset Operational Readiness (AOR) plan or strategy (If any) well defined in the orgnanization?	Yes	at high level we have PLCM that guides us		
2		Is AOR a separate department with all necessary process and procedure?	Yes	Group Capital mandate is to execute the project and handover to the client. Part of the process is to ensure the product/assets are ready for handover to the client.	However Eskom is very poor at 1. integration and defining requirements (e.g. client will bring up new requirements years after a specific phase [which maybe valid but its too late]), 2. We are not detailed orientated (generally speaking). 3. Eskom did not have sufficient recourses at start of new builds (getting recourses and training them takes time)	100%
3		AOR budget clearly defined by the business for pre-feasibility phase to handover phase (PLCM)?	Yes			
1	EQUIPMENT AND DOCUMENTATION READINESS	Are all the Regulatory and compliance requirements for all the new build systems and equipment fulfilled?	Yes	Up to handover for Boiler. RBI is being dealt with by Gx. However I cannot say the same for other packages (e.g. BOP)	need more responsibility in Eskom. I reminder the RBI team coming to site in 2015/2016 and we are in 2019 and RBI for K1 is still outstanding, and there is no action??. Now work that should have been done my others is being sent to me to complete.	
2		Are the systems/equipment delivered in line with the operational requirements?	No	Many Manufacturing defects (in the case of DBT pressure parts) which will require a lot of additional attention and earlier interventions by Gx than original plan. Also many design defects which are resulting in unreliable and unavailable units.		
3		Is the Engineering and Quality Process implemented accordingly to Achieve system clearance and Registration?	Yes	Overall, Yes. But 1. we do have situations were contactor/sub-contractor made mistakes or errors but our systems (inspections, tests, ITPs, permanent or adhoc inspectors, eng reviews..) allowed us to identify and follow a process (NCR) to get to a resolution. however this is after the fact and not proactively preventing the incident. 2. other cases were contractor purposely tried to avoid or go around Eskom (e.g. faking PWHT charts). These were still caught by Eskom but it is had for a quality system to cover everything (people can find ways around anything).		47%
4		Has the business ensured that spare equipment, or maintenance and operational services required during operation are factored into the Life cycle model?	Yes	It was considered in the early design phases but (as highlighted above) not in detail. E.g. simple drain valves are all from Germany, Why? Many more examples	we need to be more detail orientated.	
5		Is the O&M documentation made available during commissioning or operation of the asset?	Yes	Preliminary O&Ms are available during commissioning, however as-built are still outstanding for K1 which was handed over 2 years ago.	I don't think payment milestones are structured well enough to ensure we get critical outcomes from the contractor. I think with lessons from new builds we could structure contracts and contract payment structures better in future.	

6	EQUIPMENT AND DOCUMENTATION READINESS	Is the Electrical and C&I infrastructure/design adequately integrated to the mechanical equipment prior to commercialization of the asset?	Yes	There maybe one or two mistakes but looking overall at then 10s of thousands on interfaces on each unit I think we have been very successful.		
7		Is there a defined process for equipment re-location (swap) during construction?	No	The contactor has a internal 1 page procedure which is lacking a lot of details.		
8		Is the Specification (Employer's Contract) adequately detail to eliminate ambiguity?	No	I think the contract is the best that it could have been at the time (remember that the projects were rushed at the beginning due to load shedding)	we should ensure that all shortcomings that have been identified by Medupi and Kusile are documented now, or we will loose all the knowledge	
9		Is the Integrated Design Review Report sufficient for ensuring harmony between various stakeholder or interface?	No	IDR is only end of phases. The Client needs to be involved in the actual phases (with reviews of actual documents, procedures, philosophies, even manufacturing) so they can start gathering all info and knowledge to setup their systems prior to the actual handover.	I don't know if it would be successful, but maybe the project engineers should actually be Gx engineers who would on the project and then get transferred back to Gx at handover.	
10		Is the Pre-Commissioning Review Report "details" adequate for readiness of the equipment to be commissioned in a safe manner?	Yes	if people are made/held accountable then yes.		
11		Is the Handover Design Review Report (Matrix) a good tool to verify the readiness of the plant for the client to operate?	Yes	However it is only as good as the requirements included in it, and only as good as the input included.	the matrix was only developed a 1 year before actual handover. It should have been done in the design stage and included in the contract. if Gx what's some thing now and it was not take-over requirement in the contract then its an uphill battle.	47%
12		Is the Engineering Change Process, Risk Assessment, and Non-conformance Management well documented throughout the PLCM?	Yes	But we don't follow it diligently		
13		Are all the Design Documents submitted on time with As-Build Information for Operation and Maintenance (O&M)?	No		Need to setup the contract better or with the lessons from the new builds	
14		Does the project have detailed RAM (Reliability, Availability, Maintainability) Studies and is there a need to produce detailed RAMS for all the system?	No	not enough time spent on it during early design phases, also again Eskom is not detail orientated		
15		Bill of Materials documentation adequate to guide the O&M team on maintainability of the Power Plant?	No	BOM not detailed enough. Again not enough time spent during reviews of the O&M (in 2014-2016) and again not detailed enough, and Gx not involved	as per my suggestions above, Gx engineers should be seconded to the project during design and execution phases.	
16		Is there sufficient Documentation for Procurement Spare Parts during Maintenance of the Plant	No		again, if Gx was involved from the beginning we might have helped.	
17		Is the Spare Parts Documentation submitted prior to Operation	No	I assume you mean the databooks for the spares?		

1	COMPETENCY READINESS	**Is the business aware of the importance of AOR to ensure that there are right skill-sets and competencies?**	No	I don't think we still have the right skill set. We are talking about R150+ billion project and in some areas I don't think we have the right people on the project.	off course we did award contracts to well established contractors who should know what they are doing and employed a lot of quality recourses (at the beginning). It's a though one; e.g. if the project was completed with no issues then we would be having a different discussion.	20%
2		**Is there a programme to develop the staff identified for Plant Operation prior to Plant takeover?**	Yes	Training is provided. but it is only of any good if there is effort put in from the individuals. E.g. during commissioning, they could have been involved so get all the info, know-how, methods we used to commissioning, troubleshoot and resolve issues during commissioning. granted, the units are not operating as per the design intent (e.g. high spraywater, PJFF failures and pulsing issues, temp imbalances, mills...).		
3		**Does the business have a Methods to profile and assess the competency of each individual as they develop?**	No			
4		**Is the AOR team (if any) established at the right phase of the PLCM (Project Life Cycle Model) with well defined Roles and Responsibilities?**	No	it was not when I got to the project (back in 2012)		
5		**Is there continuous improvement of individual skills to effectively outline and perform tasks and activities pertaining to AOR?**	No			
1	OTHER	**Is the AOR Process (If any) complimenting the delivery of the project?**	No	I do think we do too much paperwork. 1. we need people to spend more time on site that doing paperwork. The system should be design to produce paperwork itself. E.g. if the matrix was defined early and in the contract, then as the contractor submits documents it should automatically loaded in SPO and SPO should produce the matrix. 2. we need more accountability so that we have the right people executing the projects.		50%
2		**Is there an escalation process for AOR related concerns which has not been addressed during the PLCM (if AOR exist)?**	Yes	I believe we escalate to EDWL. The EDWL can escalate to senior or even general manager. However, I have not seen/read this actual procedure		

12TH INTERVIEWEE SURVEY WITH RESPONSE						
			Interviewee Answers			
Item Number	Type	Questions	Short Answer (Yes/No)	Comments	Suggestion (Improvement)	
	GENERAL					
1		Is Asset Operational Readiness (AOR) plan or strategy (If any) well defined in the orgnanization?	Partially Fulfilled			33%
2		Is AOR a separate department with all necessary process and procedure?	No		Implement audit team to ensure compliance and lessons learnt.	
3		AOR budget clearly defined by the business for pre-feasibility phase to handover phase (PLCM)?	Partially Fulfilled			
1	EQUIPMENT AND DOCUMENTATION READINESS	Are all the Regulatory and compliance requirements for all the newbuild systems and equipment fulfilled?	Yes			56%
2		Are the systems/equipment delivered in line with the operational requirements?	Partially Fulfilled	Defects identified on new build	OEM and Eskom to develop solutions together rather than in isolation.	
3		Is the Engineering and Quality Process implemented accordingly to Achieve system clearance and Registration?	Yes			
4		Has the business ensured that spare equipment, or maintenance and operational services required during operation are factored into the Life cycle model?	No	Scope is not always well defined, in terms of spares holding, duration and	Include more details in the scope and the contract to ensure the details and	
5		Is the O&M documentation made available during commissioning or operation of the asset?	Partially Fulfilled	Contractors tend to deliver documentation late and the contracts are written in a way that is not aligned, documentation is provided post hand-over.	Update it accordingly in the scope and the contracts before award.	
6		Is the Electrical and C&I infrastructure/design adequately integrated to the mechanical equipment prior to commercialization of the asset?	Partially Fulfilled			
7		Is there a defined process for equipment re-location (swap) during construction?	Partially Fulfilled			
8		Is the Specification (Employer's Contract) adequately detail to eliminate ambiguity?	Yes			
9		Is the Intergrated Design Review Report sufficient for ensuring harmony between various stakeholder or interface?	Partially Fulfilled	IDR are completed which sometimes does not prevent challenges experienced on the project.	Ensure compliance to IDR process and ensure all stakeholders sign-off on IDR on time.	
10		Is the Pre-Commissioning Review Report "details" adequate for readiness of the equipment to be commissioned in a safe manner?	Partially Fulfilled	Not all Reviews are completed on time with relevant take holders.	Ensure compliance by all stakeholders to processes.	
11		Is the Handover Design Review Report (Matrix) a good tool to verify the readiness of the plant for the client to operate?	Yes			
12		Is the Engineering Change Process, Risk Assessment, and Non-conformance Management well documented throughout the PLCM?	Yes			
13		Are all the Design Documents submitted on time with As-Build Information for Operation and Maintenance (O&M)?	No	Contractors tend to deliver documentation late and the contracts are written in a way that is not aligned, documentation is provided post hand-over.	Update it accordingly in the scope and the contracts before award.	
14		Does the project have detailed RAM (Reliability, Availability, Maintenability) Studies and is there a need to produce detailed RAMS for all the system?	Partially Fulfilled	Dependent on the criticality of the plant.	RAM to form part of Detail Design Freeze irrespective of criticality of plant.	
15		Bill of Materials documentation adequate to guide the O&M team on maintenability of the Power Plant?	Partially Fulfilled	Dependent on the criticality of the plant and the contract.		
		Is there sufficient Documentation for Procurement Spare Parts during Maintenance of the Plant	Partially Fulfilled	Dependent on the criticality of the plant and the contract.		
9		Is the Spare Parts Documentation submitted prior to Operation	No			
1	COMPETENCY READINESS	Is the business aware of the importance of AOR to ensure that there are right skill-sets and competencies?	Partially Fulfilled			10%
2		Is there a programme to develop the staff identified for Plant Operation prior to Plant takeover?	No	Operations teams are trained and its included in contracts	Maintenance and Engineering teams need to be included in the training plans/strategy	
3		Does the business have a Methods to profile and assess the competency of each individual as they develop?	No	Well managed in operations	Maintenance and Engineering remains a challenge.	
4		Is the AOR team (if any) established at the right phase of the PLCM (Project Life Cycle Model) with well defined Roles and Responsibilities?	No	Generally tracked in execuation phase.	Should be tracked from CRA phase to ensure readiness and inclusion of holistic approach.	
5		Is there continuous improvement of individual skills to effectively outline and perform tasks and activities pertaining to AOR?	No	Well managed in operations	Maintenance and Engineering remains a challenge.	
1	OTHER	Is the AOR Process (If any) complimenting the delivery of the project?	Partially Fulfilled			75%
2		Is there an escalation process for AOR related concerns which has not been addressed during the PLCM (if AOR exist)?	Yes			

20. APPENDIX D: QUALITATIVE SURVEYS SCORING

INTERVIEWEE NUMBER 1							
Category 1: GENERAL				Category 2: EQUIPMENT AND DOCUMENTATION READINESS			
Cell 1 Validation	0	Question 1 Score	1	Cell 1 Validation	0	Question 1 Score	1
Cell 2 Validation	0	Question 2 Score	0	Cell 2 Validation	0	Question 2 Score	0.5
Cell 3 Validation	0	Question 3 Score	0.5	Cell 3 Validation	0	Question 3 Score	1
Sum of Cells Validated =	0	Sum of Scores =	1.5	Cell 4 Validation	0	Question 4 Score	1
Cell Count =	3			Cell 5 Validation	0	Question 5 Score	1
Percentage =	50%			Cell 6 Validation	0	Question 6 Score	1
Category 3: COMPETENCY READINESS				Cell 7 Validation	0	Question 7 Score	1
				Cell 8 Validation	0	Question 8 Score	1
Cell 1 Validation	0	Question 1 Score	1	Cell 9 Validation	0	Question 9 Score	1
Cell 2 Validation	0	Question 2 Score	1	Cell 10 Validation	0	Question 10 Score	0.5
Cell 3 Validation	0	Question 3 Score	0.5	Cell 11 Validation	0	Question 11 Score	1
Cell 4 Validation	0	Question 4 Score	0	Cell12 Validation	0	Question 12 Score	1
Cell 5 Validation	0	Question 5 Score	0	Cell 13 Validation	0	Question 13 Score	0.5
Sum of Cells Validated =	0	Sum of Scores =	2.5	Cell 14 Validation	0	Question 14 Score	1
Cell Count =	5			Cell 15 Validation	0	Question 15 Score	1
Percentage =	50%			Cell 16 Validation	0	Question 16 Score	1
Category 4: OTHER (IMPACT)				Cell 17 Validation	0	Question 17 Score	1
Cell 1 Validation	0	Question 1 Score	0	Sum of Cells Validated =	0	Sum of Scores =	15.5
Cell 2 Validation	0	Question 2 Score	0	Cell Count =	17		
Sum of Cells Validated =	0	Sum of Scores =	0	Percentage =	91%		
Cell Count =	2						
Percentage =	0%						

INTERVIEWEE NUMBER 2							
Category 1: GENERAL				Category 2: EQUIPMENT AND DOCUMENTATION READINESS			
Cell 1 Validation	0	Question 1 Score	0.5	Question 1 Score	0	Category Item 1	1
Cell 2 Validation	0	Question 2 Score	0	Question 2 Score	0	Category Item 2	1
Cell 3 Validation	0	Question 3 Score	0.5	Question 3 Score	0	Category Item 3	1
Sum of Cells Validated =	0	Sum of Scores =	1	Question 4 Score	0	Category Item 4	1
Cell Count =	3			Question 5 Score	0	Category Item 5	1
Percentage =	33%			Question 6 Score	-1	Category Item 6	0
Category 3: COMPETENCY READINESS				Question 7 Score	0	Category Item 7	0.5
				Question 8 Score	0	Category Item 8	1
Cell 1 Validation	0	Question 1 Score	0.5	Question 9 Score	0	Category Item 9	1
Cell 2 Validation	0	Question 2 Score	0.5	Question 10 Score	0	Category Item 10	1
Cell 3 Validation	0	Question 3 Score	0.5	Question 11 Score	0	Category Item 11	1
Cell 4 Validation	0	Question 4 Score	0.5	Question 12 Score	0	Category Item 12	1
Cell 5 Validation	0	Question 5 Score	0.5	Question 13 Score	0	Category Item 13	0
Sum of Cells Validated =	0	Sum of Scores =	2.5	Question 14 Score	0	Category Item 14	0.5
Cell Count =	5			Question 15 Score	0	Category Item 15	1
Percentage =	50%			Question 16 Score	0	Category Item 16	1
Category 4: OTHER (IMPACT)				Question 17 Score	0	Category Item 17	0.5
Cell 1 Validation	0	Question 1 Score	1	Sum of Cells Validated =	-1	Sum of Items Cat 2 =	13.5
Cell 2 Validation	0	Question 2 Score	0.5	Cell Count =	17		
Sum of Cells Validated =	0	Sum of Scores =	1.5	Percentage =	84%		
Cell Count =	2						
Percentage =	75%						

INTERVIEWEE NUMBER 3							
Category 1: GENERAL				Category 2: EQUIPMENT AND DOCUMENTATION READINESS			
Cell 1 Validation	0	Question 1 Score	0	Cell 1 Validation	0	Question 1 Score	1
Cell 2 Validation	0	Question 2 Score	0	Cell 2 Validation	0	Question 2 Score	0.5
Cell 3 Validation	0	Question 3 Score	0	Cell 3 Validation	0	Question 3 Score	1
Sum of Cells Validated =	0	Sum of Scores =	0	Cell 4 Validation	0	Question 4 Score	1
Cell Count =	3			Cell 5 Validation	0	Question 5 Score	1
Percentage =	0%			Cell 6 Validation	0	Question 6 Score	1
Category 3: COMPETENCY READINESS				Cell 7 Validation	0	Question 7 Score	0
				Cell 8 Validation	0	Question 8 Score	0.5
Cell 1 Validation	0	Question 1 Score	0.5	Cell 9 Validation	0	Question 9 Score	0.5
Cell 2 Validation	0	Question 2 Score	0.5	Cell 10 Validation	0	Question 10 Score	1
Cell 3 Validation	0	Question 3 Score	0	Cell 11 Validation	0	Question 11 Score	0
Cell 4 Validation	0	Question 4 Score	0	Cell12 Validation	0	Question 12 Score	0.5
Cell 5 Validation	0	Question 5 Score	0	Cell 13 Validation	0	Question 13 Score	0
Sum of Cells Validated =	0	Sum of Scores =	1	Cell 14 Validation	0	Question 14 Score	1
Cell Count =	5			Cell 15 Validation	0	Question 15 Score	0
Percentage =	20%			Cell 16 Validation	0	Question 16 Score	1
Category 4: OTHER (IMPACT)				Cell 17 Validation	0	Question 17 Score	0.5
Cell 1 Validation	0	Question 1 Score	0	Sum of Cells Validated =	0	Sum of Scores =	10.5
Cell 2 Validation	0	Question 2 Score	0	Cell Count =	17		
Sum of Cells Validated =	0	Sum of Scores =	0	Percentage =	62%		
Cell Count =	2						
Percentage =	0%						

INTERVIEWEE NUMBER 4							
Category 1: GENERAL				Category 2: EQUIPMENT AND DOCUMENTATION READINESS			
Cell 1 Validation	0	Question 1 Score	1	Question 1 Score	0	Category Item 1	1
Cell 2 Validation	0	Question 2 Score	1	Question 2 Score	0	Category Item 2	1
Cell 3 Validation	0	Question 3 Score	1	Question 3 Score	0	Category Item 3	1
Sum of Cells Validated =	0	Sum of Scores =	3	Question 4 Score	0	Category Item 4	0.5
Cell Count =	3			Question 5 Score	0	Category Item 5	1
Percentage =	100%			Question 6 Score	0	Category Item 6	1
Category 3: COMPETENCY READINESS				Question 7 Score	0	Category Item 7	1
				Question 8 Score	0	Category Item 8	1
Cell 1 Validation	0	Question 1 Score	1	Question 9 Score	0	Category Item 9	0.5
Cell 2 Validation	0	Question 2 Score	1	Question 10 Score	0	Category Item 10	1
Cell 3 Validation	0	Question 3 Score	0.5	Question 11 Score	0	Category Item 11	1
Cell 4 Validation	0	Question 4 Score	0.5	Question 12 Score	0	Category Item 12	1
Cell 5 Validation	0	Question 5 Score	1	Question 13 Score	0	Category Item 13	0
Sum of Cells Validated =	0	Sum of Scores =	4	Question 14 Score	0	Category Item 14	1
Cell Count =	5			Question 15 Score	0	Category Item 15	1
Percentage =	80%			Question 16 Score	0	Category Item 16	1
Category 4: OTHER (IMPACT)				Question 17 Score	0	Category Item 17	0
Cell 1 Validation	0	Question 1 Score	1	Sum of Cells Validated =	0	Sum of Items Cat 2 =	14
Cell 2 Validation	0	Question 2 Score	1	Cell Count =	17		
Sum of Cells Validated =	0	Sum of Scores =	2	Percentage =	82%		
Cell Count =	2						
Percentage =	100%						

INTERVIEWEE NUMBER 5							
Category 1: GENERAL				Category 2: EQUIPMENT AND DOCUMENTATION READINESS			
Cell 1 Validation	0	Question 1 Score	0.5	Cell 1 Validation	0	Question 1 Score	1
Cell 2 Validation	0	Question 2 Score	0	Cell 2 Validation	0	Question 2 Score	0.5
Cell 3 Validation	-1	Question 3 Score	0	Cell 3 Validation	0	Question 3 Score	1
Sum of Cells Validated =	-1	Sum of Scores =	0.5	Cell 4 Validation	-1	Question 4 Score	0
Cell Count =	3			Cell 5 Validation	0	Question 5 Score	1
Percentage =	25%			Cell 6 Validation	0	Question 6 Score	1
Category 3: COMPETENCY READINESS				Cell 7 Validation	0	Question 7 Score	1
				Cell 8 Validation	0	Question 8 Score	0
Cell 1 Validation	0	Question 1 Score	1	Cell 9 Validation	0	Question 9 Score	1
Cell 2 Validation	0	Question 2 Score	1	Cell 10 Validation	0	Question 10 Score	1
Cell 3 Validation	-1	Question 3 Score	0	Cell 11 Validation	0	Question 11 Score	1
Cell 4 Validation	-1	Question 4 Score	0	Cell12 Validation	0	Question 12 Score	1
Cell 5 Validation	0	Question 5 Score	0	Cell 13 Validation	0	Question 13 Score	1
Sum of Cells Validated =	-2	Sum of Scores =	2	Cell 14 Validation	0	Question 14 Score	0
Cell Count =	5			Cell 15 Validation	0	Question 15 Score	0
Percentage =	67%			Cell 16 Validation	-1	Question 16 Score	0
Category 4: OTHER (IMPACT)				Cell 17 Validation	0	Question 17 Score	1
Cell 1 Validation	0	Question 1 Score	0	Sum of Cells Validated =	-2	Sum of Scores =	11.5
Cell 2 Validation	0	Question 2 Score	0	Cell Count =	17		
Sum of Cells Validated =	0	Sum of Scores =	0	Percentage =	77%		
Cell Count =	2						
Percentage =	0%						

INTERVIEWEE NUMBER 6							
Category 1: GENERAL				Category 2: EQUIPMENT AND DOCUMENTATION READINESS			
Cell 1 Validation	0	Category Item 1	1	Cell 1 Validation	0	Question 1 Score	1
Cell 2 Validation	0	Category Item 2	1	Cell 2 Validation	0	Question 2 Score	1
Cell 3 Validation	0	Category Item 3	0	Cell 3 Validation	0	Question 3 Score	1
Sum of Cells Validated =	0	Sum of Items Cat 1 =	2	Cell 4 Validation	0	Question 4 Score	1
Cell Count =	3			Cell 5 Validation	0	Question 5 Score	1
Percentage =	67%			Cell 6 Validation	0	Question 6 Score	1
Category 3: COMPETENCY READINESS				Cell 7 Validation	0	Question 7 Score	1
				Cell 8 Validation	0	Question 8 Score	0
Cell 1 Validation	0	Question 1 Score	1	Cell 9 Validation	0	Question 9 Score	1
Cell 2 Validation	0	Question 2 Score	1	Cell 10 Validation	0	Question 10 Score	1
Cell 3 Validation	0	Question 3 Score	1	Cell 11 Validation	0	Question 11 Score	1
Cell 4 Validation	0	Question 4 Score	1	Cell12 Validation	0	Question 12 Score	1
Cell 5 Validation	0	Question 5 Score	1	Cell 13 Validation	0	Question 13 Score	1
Sum of Cells Validated =	0	Sum of Scores =	5	Cell 14 Validation	0	Question 14 Score	1
Cell Count =	5			Cell 15 Validation	0	Question 15 Score	1
Percentage =	100%			Cell 16 Validation	0	Question 16 Score	1
Category 4: OTHER (IMPACT)				Cell 17 Validation	0	Question 17 Score	1
Cell 1 Validation	0	Question 1 Score	1	Sum of Cells Validated =	0	Sum of Scores =	16
Cell 2 Validation	0	Question 2 Score	1	Cell Count =	17		
Sum of Cells Validated =	0	Sum of Scores =	2	Percentage =	94%		
Cell Count =	2						
Percentage =	100%						

INTERVIEWEE NUMBER 7							
Category 1: GENERAL				Category 2: EQUIPMENT AND DOCUMENTATION READINESS			
Cell 1 Validation	0	Question 1 Score	0	Cell 1 Validation	0	Question 1 Score	1
Cell 2 Validation	0	Question 2 Score	0	Cell 2 Validation	0	Question 2 Score	1
Cell 3 Validation	0	Question 3 Score	0	Cell 3 Validation	0	Question 3 Score	1
Sum of Cells Validated =	0	Sum of Scores =	0	Cell 4 Validation	0	Question 4 Score	1
Cell Count =	3			Cell 5 Validation	0	Question 5 Score	1
Percentage =	0%			Cell 6 Validation	0	Question 6 Score	1
Category 3: COMPETENCY READINESS				Cell 7 Validation	0	Question 7 Score	0
				Cell 8 Validation	0	Question 8 Score	0
Cell 1 Validation	0	Question 1 Score	0	Cell 9 Validation	0	Question 9 Score	0.5
Cell 2 Validation	0	Question 2 Score	0.5	Cell 10 Validation	0	Question 10 Score	0.5
Cell 3 Validation	0	Question 3 Score	0	Cell 11 Validation	0	Question 11 Score	0.5
Cell 4 Validation	0	Question 4 Score	0	Cell12 Validation	0	Question 12 Score	1
Cell 5 Validation	0	Question 5 Score	0	Cell 13 Validation	0	Question 13 Score	0
Sum of Cells Validated =	0	Sum of Scores =	0.5	Cell 14 Validation	0	Question 14 Score	1
Cell Count =	5			Cell 15 Validation	0	Question 15 Score	1
Percentage =	10%			Cell 16 Validation	0	Question 16 Score	0.5
Category 4: OTHER (IMPACT)				Cell 17 Validation	0	Question 17 Score	0
Cell 1 Validation	0	Question 1 Score	0	Sum of Cells Validated =	0	Sum of Scores =	11
Cell 2 Validation	0	Question 2 Score	0	Cell Count =	17		
Sum of Cells Validated =	0	Sum of Scores =	0	Percentage =	65%		
Cell Count =	2						
Percentage =	0%						

INTERVIEWEE NUMBER 8							
Category 1: GENERAL				Category 2: EQUIPMENT AND DOCUMENTATION READINESS			
Cell 1 Validation	0	Question 1 Score	0.5	Cell 1 Validation	0	Question 1 Score	0.5
Cell 2 Validation	0	Question 2 Score	0	Cell 2 Validation	0	Question 2 Score	0.5
Cell 3 Validation	0	Question 3 Score	0	Cell 3 Validation	0	Question 3 Score	0
Sum of Cells Validated =	0	Sum of Scores =	0.5	Cell 4 Validation	0	Question 4 Score	1
Cell Count =	3			Cell 5 Validation	0	Question 5 Score	1
Percentage =	17%			Cell 6 Validation	0	Question 6 Score	0.5
Category 3: COMPETENCY READINESS				Cell 7 Validation	0	Question 7 Score	0.5
				Cell 8 Validation	0	Question 8 Score	0
Cell 1 Validation	0	Question 1 Score	1	Cell 9 Validation	0	Question 9 Score	1
Cell 2 Validation	0	Question 2 Score	1	Cell 10 Validation	0	Question 10 Score	1
Cell 3 Validation	0	Question 3 Score	1	Cell 11 Validation	0	Question 11 Score	1
Cell 4 Validation	0	Question 4 Score	1	Cell12 Validation	0	Question 12 Score	0
Cell 5 Validation	-1	Question 5 Score	0	Cell 13 Validation	0	Question 13 Score	0.5
Sum of Cells Validated =	-1	Sum of Scores =	4	Cell 14 Validation	0	Question 14 Score	1
Cell Count =	5			Cell 15 Validation	0	Question 15 Score	1
Percentage =	100%			Cell 16 Validation	0	Question 16 Score	0.5
Category 4: OTHER (IMPACT)				Cell 17 Validation	0	Question 17 Score	1
Cell 1 Validation	-1	Question 1 Score	0	Sum of Cells Validated =	0	Sum of Scores =	11
Cell 2 Validation	0	Question 2 Score	1	Cell Count =	17		
Sum of Cells Validated =	-1	Sum of Scores =	1	Percentage =	65%		
Cell Count =	2						
Percentage =	100%						

INTERVIEWEE NUMBER 9							
Category 1: GENERAL				Category 2: EQUIPMENT AND DOCUMENTATION READINESS			
Cell 1 Validation	0	Question 1 Score	0	Cell 1 Validation	0	Question 1 Score	1
Cell 2 Validation	0	Question 2 Score	0	Cell 2 Validation	0	Question 2 Score	1
Cell 3 Validation	0	Question 3 Score	0	Cell 3 Validation	0	Question 3 Score	1
Sum of Cells Validated =	0	Sum of Scores =	0	Cell 4 Validation	0	Question 4 Score	1
Cell Count =	3			Cell 5 Validation	0	Question 5 Score	1
Percentage =	0%			Cell 6 Validation	-1	Question 6 Score	0
Category 3: COMPETENCY READINESS				Cell 7 Validation	0	Question 7 Score	0
				Cell 8 Validation	0	Question 8 Score	0
Cell 1 Validation	0	Question 1 Score	1	Cell 9 Validation	0	Question 9 Score	1
Cell 2 Validation	0	Question 2 Score	0	Cell 10 Validation	0	Question 10 Score	1
Cell 3 Validation	0	Question 3 Score	0	Cell 11 Validation	0	Question 11 Score	1
Cell 4 Validation	0	Question 4 Score	0	Cell12 Validation	0	Question 12 Score	1
Cell 5 Validation	0	Question 5 Score	0	Cell 13 Validation	0	Question 13 Score	0.5
Sum of Cells Validated =	0	Sum of Scores =	1	Cell 14 Validation	0	Question 14 Score	1
Cell Count =	5			Cell 15 Validation	0	Question 15 Score	0
Percentage =	20%			Cell 16 Validation	0	Question 16 Score	1
Category 4: OTHER (IMPACT)				Cell 17 Validation	0	Question 17 Score	1
Cell 1 Validation	0	Question 1 Score	1	Sum of Cells Validated =	-1	Sum of Scores =	12.5
Cell 2 Validation	0	Question 2 Score	0	Cell Count =	17		
Sum of Cells Validated =	0	Sum of Scores =	1	Percentage =	78%		
Cell Count =	2						
Percentage =	50%						

INTERVIEWEE NUMBER 10							
Category 1: GENERAL				Category 2: EQUIPMENT AND DOCUMENTATION READINESS			
Cell 1 Validation	0	Question 1 Score	0	Cell 1 Validation	0	Question 1 Score	1
Cell 2 Validation	0	Question 2 Score	0	Cell 2 Validation	0	Question 2 Score	1
Cell 3 Validation	0	Question 3 Score	0	Cell 3 Validation	0	Question 3 Score	1
Sum of Cells Validated =	0	Sum of Scores =	0	Cell 4 Validation	0	Question 4 Score	0.5
Cell Count =	3			Cell 5 Validation	0	Question 5 Score	1
Percentage =	0%			Cell 6 Validation	0	Question 6 Score	1
Category 3: COMPETENCY READINESS				Cell 7 Validation	0	Question 7 Score	1
				Cell 8 Validation	0	Question 8 Score	0.5
Cell 1 Validation	0	Question 1 Score	0	Cell 9 Validation	0	Question 9 Score	0
Cell 2 Validation	0	Question 2 Score	0	Cell 10 Validation	0	Question 10 Score	1
Cell 3 Validation	0	Question 3 Score	0	Cell 11 Validation	0	Question 11 Score	0
Cell 4 Validation	0	Question 4 Score	0	Cell12 Validation	0	Question 12 Score	1
Cell 5 Validation	0	Question 5 Score	0	Cell 13 Validation	0	Question 13 Score	0
Sum of Cells Validated =	0	Sum of Scores =	0	Cell 14 Validation	0	Question 14 Score	0
Cell Count =	5			Cell 15 Validation	0	Question 15 Score	1
Percentage =	0%			Cell 16 Validation	0	Question 16 Score	1
Category 4: OTHER (IMPACT)				Cell 17 Validation	0	Question 17 Score	1
Cell 1 Validation	0	Question 1 Score	0	Sum of Cells Validated =	0	Sum of Scores =	12
Cell 2 Validation	-1	Question 2 Score	0	Cell Count =	17		
Sum of Cells Validated =	-1	Sum of Scores =	0	Percentage =	71%		
Cell Count =	2						
Percentage =	0%						

INTERVIEWEE NUMBER 11							
Category 1: GENERAL				Category 2: EQUIPMENT AND DOCUMENTATION READINESS			
Cell 1 Validation	0	Question 1 Score	1	Cell 1 Validation	0	Question 1 Score	1
Cell 2 Validation	0	Question 2 Score	1	Cell 2 Validation	0	Question 2 Score	0
Cell 3 Validation	0	Question 3 Score	1	Cell 3 Validation	0	Question 3 Score	1
Sum of Cells Validated =	0	Sum of Scores =	3	Cell 4 Validation	0	Question 4 Score	1
Cell Count =	3			Cell 5 Validation	0	Question 5 Score	1
Percentage =	100%			Cell 6 Validation	0	Question 6 Score	1
Category 3: COMPETENCY READINESS				Cell 7 Validation	0	Question 7 Score	0
				Cell 8 Validation	0	Question 8 Score	0
Cell 1 Validation	0	Question 1 Score	0	Cell 9 Validation	0	Question 9 Score	0
Cell 2 Validation	0	Question 2 Score	1	Cell 10 Validation	0	Question 10 Score	1
Cell 3 Validation	0	Question 3 Score	0	Cell 11 Validation	0	Question 11 Score	1
Cell 4 Validation	0	Question 4 Score	0	Cell12 Validation	0	Question 12 Score	1
Cell 5 Validation	0	Question 5 Score	0	Cell 13 Validation	0	Question 13 Score	0
Sum of Cells Validated =	0	Sum of Scores =	1	Cell 14 Validation	0	Question 14 Score	0
Cell Count =	5			Cell 15 Validation	0	Question 15 Score	0
Percentage =	20%			Cell 16 Validation	0	Question 16 Score	0
Category 4: OTHER (IMPACT)				Cell 17 Validation	0	Question 17 Score	0
Cell 1 Validation	0	Question 1 Score	0	Sum of Cells Validated =	0	Sum of Scores =	8
Cell 2 Validation	0	Question 2 Score	1	Cell Count =	17		
Sum of Cells Validated =	0	Sum of Scores =	1	Percentage =	47%		
Cell Count =	2						
Percentage =	50%						

INTERVIEWEE NUMBER 12							
Category 1: GENERAL				Category 2: EQUIPMENT AND DOCUMENTATION READINESS			
Cell 1 Validation	0	Question 1 Score	0.5	Cell 1 Validation	0	Question 1 Score	1
Cell 2 Validation	0	Question 2 Score	0	Cell 2 Validation	0	Question 2 Score	0.5
Cell 3 Validation	0	Question 3 Score	0.5	Cell 3 Validation	0	Question 3 Score	1
Sum of Cells Validated =	0	Sum of Scores =	1	Cell 4 Validation	0	Question 4 Score	0
Cell Count =	3			Cell 5 Validation	0	Question 5 Score	0.5
Percentage =	33%			Cell 6 Validation	0	Question 6 Score	0.5
Category 3: COMPETENCY READINESS				Cell 7 Validation	0	Question 7 Score	0.5
				Cell 8 Validation	0	Question 8 Score	1
Cell 1 Validation	0	Question 1 Score	0.5	Cell 9 Validation	0	Question 9 Score	0.5
Cell 2 Validation	0	Question 2 Score	0	Cell 10 Validation	0	Question 10 Score	0.5
Cell 3 Validation	0	Question 3 Score	0	Cell 11 Validation	0	Question 11 Score	1
Cell 4 Validation	0	Question 4 Score	0	Cell12 Validation	0	Question 12 Score	1
Cell 5 Validation	0	Question 5 Score	0	Cell 13 Validation	0	Question 13 Score	0
Sum of Cells Validated =	0	Sum of Scores =	0.5	Cell 14 Validation	0	Question 14 Score	0.5
Cell Count =	5			Cell 15 Validation	0	Question 15 Score	0.5
Percentage =	10%			Cell 16 Validation	0	Question 16 Score	0.5
Category 4: OTHER (IMPACT)				Cell 17 Validation	0	Question 17 Score	0
Cell 1 Validation	0	Question 1 Score	0.5	Sum of Cells Validated =	0	Sum of Scores =	9.5
Cell 2 Validation	0	Question 2 Score	1	Cell Count =	17		
Sum of Cells Validated =	0	Sum of Scores =	1.5	Percentage =	56%		
Cell Count =	2						
Percentage =	75%						