School of Civil and Mechanical Engineering

An Investigation to the Main Components of the Project Study Phase Deliverables and an In-depth Review into the Industry's Schedule Development Practices

Sam Rad

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DECLARATION

This thesis contains no material, which has been accepted for the award of any other degree or diploma in any university.

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgement has been made.

Signature:

Date: 18 December 2020

ABSTRACT

Construction projects have inherent risk and uncertainty primarily due to uniqueness of undertaking, complexity, use of limited resources, and time and cost constraints. One of the key causes of construction project's productivity issues and delays are insufficient attention during the project 'study phase'. A critical success factor for construction projects is providing effective attention to this phase and finding an appropriate basis to eliminate the project delays accordingly. In certain developing countries, standard processes do not exist that define the project study phase components, in particular project management deliverables. Consequently, the project management team defines its own unique (and often non-structured) approach to execute the project based on their experiences. The significance of this subject and importance to industry is the key impetus to investigate the overall parameters in the project Study phase and to identify the components of the key deliverables. The driver for this research is to provide a recommended set of deliverables that can support construction companies to prepare unique procedures at the project study phase.

This research ultimately has various benefits for key project stakeholders in the construction industry such as:

- Availability of the structured comprehensive studies at the end of study phase will increase confidence levels on meeting the project objectives and minimise risk.
- Considering the main components of the project management deliverables will support engineering consultants to set robust criteria to validate their study reports for the future projects.
- Improvement to the project productivity in the construction phase is expected as there is a demonstrated correlation between the study phase and construction productivity.
- For some developing countries, this research will make a significant contribution to knowledge through the development of project Study phase deliverables in construction projects. Additionally, this research can assist to make a unique basis for preparation of the study phase report including a framework of project management deliverables. Outcomes will be most effective to minimize or eliminate construction delays. The study phase structured outcomes can be stipulated in the scope of works in general conditions of typical construction contracts.
- Construction delays and project cost overrun can be minimised by populating the

mandatory study deliverables.

- Comprehensive time management studies (schedule development) as a case study was performed in one of the mining projects in WA that can be considered as one of industry`s best practices. In this case, project time estimates, schedule elements, schedule basis, cost & time trade-off practice, progress curves, contingencies & risk analysis, and schedule conformance index have been compiled. This has been introduced to provide a standardised benchmark and validation of the structured study phase approach proposed.
- The approach taken in this case study supports clients & project managers in construction companies to understand the level of maturity of the studies implemented by engineers to make strategic decisions before progressing to the subsequent phase of the project (proceeding the study phase).
- Study components can be applied as a key guideline for consultants in developing countries to ensure all aspects of project studies are accurately defined and mapped, however study phase deliverables derived from simple contract's requirements may not be sufficient and projects may fail due to incomplete studies.
- A typical roadmap describing the project process through initiation to completion phases has been provided at the end of this case study that normally is being used by lead oil & Gas/ Mining/ and construction companies to validate a set of defined project objectives at each stage gates.
- The mandatory deliverables and its key components can be applied as a standardized checklist to both measure the quality of the study works as well as its conformance to similar successful projects. This further forms the basis of evaluating successful completion.
- Following the process map in this case study and undertaking sufficient detailed studies, design work, estimates and analysis associated with the project aims clients to minimize the uncertainty and achieve a significant level of accuracy before a project is authorized to execution phase.

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ABBREVIATIONS AND DEFINITIONS

Abbreviations	Definitions
AFC	Approved for Construction
AFD	Approved for Design
AGV	Automated Guided Vehicles
BCR	Budget Cost Ratio
BOE	Basis of Estimate
BOM	Bill of Material
BOOT	Build Own Operate Transfer
BOS	Basis of Schedule
CAPEX	Capital Expenditure
CBS	Cost Breakdown Structure
CCPM	Critical chain project management
CCTV	Closed Circuit TV
CI	Conformance Index
CII	Construction Industry Institute
CMP	Construction Management Plan
CPI	Cost Performance Index
CPM	Critical Path Method
CRC	Core Required Components
CRCs	Cost-reimbursement contracts
DC	Design and Contract
DCR	Design Change Request
DPS	Definition Phase Study
ECI	Early Contractor Involvement

EDS	Equipment Data Sheet
EIA	Environmental Impact Assessment
EOI	Expression of Interest
EPCM	Engineering, Procurement, and Construction Management
ERC	Earned Value Management Components
ESMP	Environmental and Social Management Plan
EVA	Economic Value Added
EVM	Earned Value Management
FAT	Factory Acceptance Test
FEED	Front End Engineering Design
FEL	Front End Loading
FPCs	Fixed-price contracts
FUSP	Functional Specification
GA	General Arrangement
GERT	Graphical Evaluation and Review Technique
HAZAN	Hazard Analysis
HAZID	Hazard Identification
HAZOP	Hazard and Operability Study
HMI	Human Machine Interface
HR	Human Resource
HSEC	Health Safety Environment and Community
HV	High Voltage
ICs	Incentive contracts
IFD	Issued for Design
IFR	Issued for Review

IFSD	Issued for Shop Detailing
IFT	Issued for Tender
IRR	Internal Rate of Return
ISO	International Standards Organization
ITP	Inspection and Test Plan
JB	Junction Box
KPI	Key Performance Indicator
KRC	Risk Required Components
LAN	Local Area Network
LDE	Lead Discipline Engineers
LOB	Line of Balance
LSM	Linear Scheduling Method
LV	Light Vehicle
MPO	Master Program Office
MTO	Material Take Off
NOA	Notice of Award
NOE	Notice of Energisation
NPI	Non-Process Infrastructure
NPV	Net Present Value
OBS	Organizational Breakdown Structure
OC	Opportunity Cost
OHS	Occupational Health and Safety
OPEX	Operational Expenditure
P&ID	Piping and Instrumentation Diagram
PI	Product Information

PBS	Package Breakdown Structure
PCOR	Project Close Out Report
PDN	Project Deviation Notice
PE	Process Equipment
PEP	Project Execution Plan
PERT	Program Evaluation and Review Technique
PFD	Process Flow Diagram
PL	Portal Lathes
PLC	Programmable Logic Controller
PMBOK	Project Management Body of Knowledge
PMI	Project Management Institute
PMIS	Project Management Information System
PP	Payback Period
PPE	Personal Protective Equipment
PV	Performance Verification
QA	Quality Assurance
QC	Quality Control
QRA	Quantitative Risk Analysis
RFA	Request for Approval
RFP	Request for Proposal
RFQ	Request for Quote
ROM	Rough Order of Magnitude
ROS	Required on Site
RRC	Resource Required Components
RSRS	Rolling Stock Reliability System

RWP	Requirement Work Plan
SCI	Schedule Critically Index
SIA	Social Impact Analysis
SID	Safety in Design
SIL	Safety Integrity Level
SLD	Single Line Diagram
SMART	Specific, Measurable, Achievable, Relevant, and Time limited
SMP	schedule management plan
SOR	Statement of Requirements
SOW	Scope of Work
SPI	Schedule Performance Index
SPS	Selection Phase Study
SSI	Schedule Sensitivity Index
TF	Total Float
TQ	Technical Query
VE	Value Engineering
VIP	Value Improvement Plan
VURS	Valid User Requirement Specification
WA	Western Australia
WAN	Wide Area Network
WBS	Work Breakdown Structure
WP	Work Pack

1. INTRODUCTION

1.1. Background

Time, Cost & Quality performance are the main measures of project success. In certain developing countries, it is considered rare for construction projects to meet the cost, time and quality constraints. Delays are consistently one of the more significant concerns of project management in construction industries. Insufficient attention to the project's study phase are historically recorded as one of the key root causes of poor project productivity and project delays. For example, poor estimation practice in Saudi Arabia [Al-Barak, 1993], poor design, change management orders, and unforeseen site conditions in Jordan [Al-Momani, 2000], Financial constraints and lack of experiences in construction business in Kuwait [Koushki et al, 2005], Inadequate early planning, and poor site management in UAE [Faridi and El-Sayegh, 2006], Ineffective planning & scheduling and shortage of labour in Saudi Arabia [Assaf and Al-Hejji, 2006], Financial problem, Poor site management, and lack of Contractor's experiences in Malaysia [Sambasivan and Soon, 2007], Contract Management, Site management, improper planning, and lack of communications in Iran [Khoshgoftar M, 2010], Not selecting competent subcontractors, poor management of changes, basic & detail designs errors in Iran [Afshari H, 2010], And a summary of delay`s classifications in different countries [Chidambaram R, SP Narayanan and Arazi B , 2012]. It can be stated that all the above project management failures originated from improper or insufficient study services.

In the universe of project management, the project life cycle is comprised of four phases: Initiation, Planning, Execution, and close up [PMBOK Guide Fifth Edition, 2013]. A clear understanding of these phases is essential for clients, project management and organizations to enter subsequent phases with minimum risk.

The initiation & planning phases can be categorised as study phase that have most influences on the execution phase. For further clarification in this research, the study phase has been broken down into identification, selection, and definition phases. In construction industries, detailed engineering, procurement, construction, and commissioning can be classified in the execution phase.

Historically, a lack of attention and neglecting of the study phase has resulted in delays in the execution phase. Evidence demonstrates that the quality of deliverables at study phases are directly related to construction productivities [Kadir A, 1995] and consequently can have significant impact to construction schedules.

From my past experiences in some national projects in the Middle East and by extensive literature review and interviews with experienced practitioners, It was found that the scope of work, time & budget allocated for the study services are generally not sufficient in the contract package, hence, incomplete reports and disqualified deliverables can be expected as a result of this phase. This often results in the most critical key requirements being neglected in the project life cycle, meanwhile some major causes of delays that are related directly to study deliverables such as project management & basic engineering services arise in the execution phase with more risk, time & cost.

Furthermore, by detailed studies on the study report of some major international projects in the Middle East, it is a general notion that project managers usually manage projects based on their traditional experience rather than following the organizational procedures and using professional project management knowledge. For instance, the project study report includes adequate works on engineering designs, drawings & specifications in all aspects of civil, structural, architectural, mechanical & process, electrical, instrument & control, Geotechnical & Hydrology disciplines, however limited attention to the project management deliverables such as market studies, feasibility studies, project quality, human resource, contract & procurement, project controls including cost, scheduling, estimating, risks, HSEC etc.

Conversely, in some developed countries, the investment in the study phase is a fundamental focus due to the wide understand that the study phase emphasis has a direct impact to key project success factors during execution. Comprehensive studies are executed during this phase to ensure management and clients allocate appropriate time and funding to the subsequent phase of project (with appropriate allocated contingency). It can be stated that this provides a fundamental basis for the execution team to perform the project execution phase smoothly with high efficiencies and performance. Consequently, delays will be minimized or even eliminated during the execution phase.

1.2. Research Method

This research shall be carried through consultation with various construction companies, construction industry expert's experience, face-to-face interviews and review of appropriate literature. This thesis addresses two distinct methods of study, firstly qualitative research consisting of the following tasks:

- Data collection from the leading construction companies.
- Review of the organisational reports in the project study phase.
- Face to face interview with construction experts & engineering professionals to develop the deliverables list.

Secondly, quantitative research including:

- Investigate study phase deliverables list and their main components.
- Selection of an EPCM project and run study phase deliverables. In this case, project time management (schedule development) will be reviewed and analysed.
- Results from the schedule data analysis presented.

1.3. Research Aim and Objectives

The proposed research program aims to critically review key components of the project study phases in the construction industries and provide an in-depth study into the project controls deliverables (in this case schedule development practice). The key objective of this research are outlined below:

- To carry out a comprehensive study on the list of activities and deliverables that must be identified by the end of study phase with basis and justification of its philosophy for use.
- To generate a general guideline to assist in defining the overall parameters of the project study phase. It is critical that the recommended methods in this research can assist to form a basis for the preparation of unique procedures and unique project structures. It is envisaged that the greatest benefits are expected from engineering consultants to prepare a sufficient study report that allows clients to enter the project execution phase with low risks & delays.
- Aim to deliver a standardised framework for EPC & EPCM projects to carry out a study phase assessment and to identify its level of quality & maturity.
- The approach will support engineers & project managers in construction companies to increase the chance of project success and to minimize the rework and study costs by setting up the clear study definition, required deliverables list and key components.

The proposed research is also only applicable to the major national and international construction projects usually in the form of EPC and EPCM contract agreement in a variety of industry sectors, including Civil Construction, Oil & Gas, Mining, Building, Dam and Rail. Any projects other than construction type (e.g. IT & research projects) have different phases/ deliverables require a different set of methodology & guideline beyond our investigations.

1.4. Research Layout

An outline of the research chapters is provided below:

- **Chapter 1** defines the overall content of the research project and highlights the significance of the work.
- **Chapter 2** describes an overview of the project definition, project life cycle & phases, and a brief definition of Front-End Loading and Early Works.
- **Chapter 3** explores the project study development and population of the project business case study, which shall be carried out during the selection phase of the project. These tasks & related mandatory deliverables to be undertaken by engineers are usually based on the requirements defined in the contract agreements.
- **Chapter 4** focuses on comprehensive studies on the project management deliverables and the processes that are required to be completed by the end of study phase. This information is gathered and compiled from various construction expert`s practical experiences, established procedures of the lead construction companies, face to face interviews, and best practices of successful infrastructure projects.
- **Chapters 5, 6 & 7** reviews the project core work deliverables and process at a detailed level that must be carried out prior to commencing the project execution phase. These chapters will address planning for Engineering, Contract & Procurement, Construction & Commissioning tasks and related key deliverables.
- **Chapter 8** outlines an overview of the schedule development practice, time management components, and schedule basis and range analysis of a key selected construction project. This includes schedule analysis, results, recommendations and further research which emanates from the findings.

2. PROJECT PHASES

2.1. Introduction

A project is unique and is of definite duration. Projects aim to deliver an output or deliverables and their success will be evaluated with respect to the delivery of time and cost. The purpose of this chapter is to investigate the standardized project phases along with key components that are currently being used by lead construction companies at all stages of the project life cycle from initiation to completion. This chapter additionally aims to provide other companies/consultants a framework for understanding distinctive deliverables and the minimum requirements as per contract agreement.

A project may be divided into several phases. A project phase is a collection of logically related project activities that culminates in the completion of one or more deliverables. Project phases are typically carried out sequentially with specific duration and effort. The number of phases primarily depends on the size, the nature of the specific project, the style of project team or organization and complexity of the project [PMBOK Guide Fifth Edition, 2013].

Each phase has its own specific activities, skill sets, locations, and organizations. Deliverables shall be handed over at the closure of each phase that represents a stage gate to reassess, to continue or terminate the project. Each phase of project is only considered complete when the review and approval process have been carried out and a decision has been made to proceed or not to proceed to the next phase.

Some organizations have an established policy that standardizes all project phases. Each phase is designed to ensure proper project control and to attain desired product or result.

A project life cycle is the series of phases that a project passes through from its initiation to its closure. Phases are generally time bounded with start and finish dates. The unique aspect of industry, technology or organization can shape it. It provides the basic framework for managing the project and can be classified to planned driven and change driven approaches [Archibald, R, 2003].

In the universe of project management, projects vary in size and complexity and all projects are comprised to the five generic life cycle structure as shown in Figure 2-1[Megginson, 2012]:

- Identification/Pre-feasibility

- Selection
- Definition/Planning
- Execution, and
- Close up

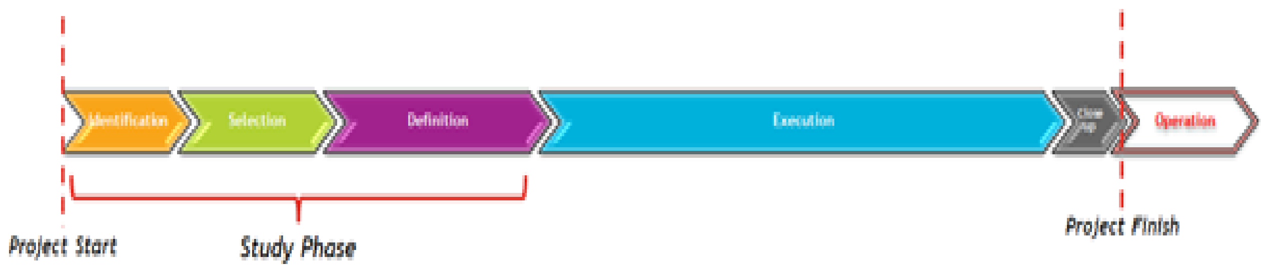


Figure 2-1 Typical Project Phases

The initial three phases (Identification, Selection, and Definition) can be grouped as the ‘study phase’ and a clear understanding of these phases is considered essential for clients, project management and organizations prior to entering the next phase with minimum risk.

Certain project phases can overlap to conserve time and to expedite delivery. This technique is used to compress the project schedule if required resources are available or manageable. Project life cycle usually has the following characteristics as demonstrated in Figure 2-2 [Wideman R, 2004]:

- The level of information, cost of corrective actions and changes, required resources, and project expenses are minimum at start of project and increases as the project progresses towards execution.
- The ability to change with minimum impacts to the project, project risks & uncertainties are highest at the commencement of project and decreases as the project approaches the closure.

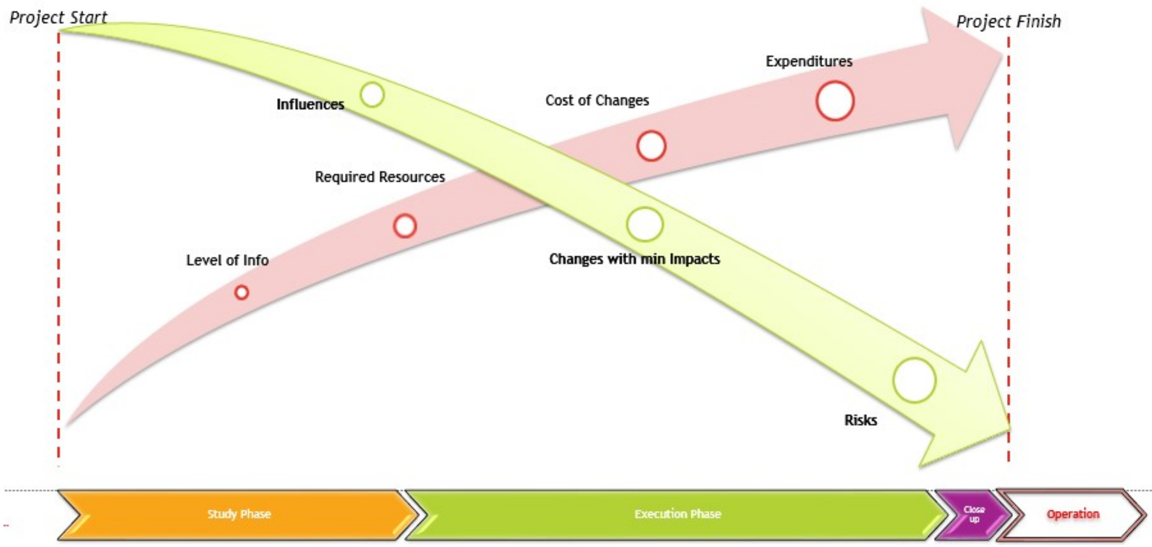


FIGURE 2-2 **Project Characteristic**

Planning for the next phase is a critical element to be considered during each of project phases. The activities to be undertaken in each phase are based on requirements defined in the contract agreements.

Projects are successfully progressed by ensuring each phase builds on sound decision-making process supported by robust procedures and practices from the preceding phase to ensure that projects [Ritz G, 1994]:

- Are delivered in alignment with corporate (strategic) principles with respect to health, safety, community relations and environmental performance
- Have a clearly defined and tangible scope
- Completed safely, within budget and on time
- Are reliable, maintainable, and operable
- Perform as expected, and
- Aim to maintain or improve the value of the business case

A project is initiated where the idea is established with stated objectives and expected benefits. This process is very important in that it is the authorisation for work to commence on the project and in this regard the project charter is the key to validate the project and to appoint a project manager [Zambruski M, 2009].

2.1.1 Identification Phase Study

The identification phase study is the first stage of project study development. The purpose of the identification phase is to identify the potential strategic investment alternatives and projects configuration alternatives to be assessed further in the selection phase. The value of a project investment opportunity can be maximizing by meeting the market requirements for the specific products, achieving the planned production rate, optimizing project development cycle time, minimizing risks, and maximizing net present value (NPV) and project internal rate of return IRR.[Thompson A, 2005].

The below requirements are critical in the identification phase of the study report (as illustrated in Figure 2-3)[Bhp PDM, 2011]:

- Preliminary needs analysis
- Growth needs of the business
- Assessment of existing assets and projects capability
- Potential of the new or expanded opportunity
- Location that project can be operated successfully
- Technical process and features
- Potential markets for produced products
- Baseline site conditions
- Surveying and site investigations
- Required permits and its time impact
- General features of the opportunity
- Threats, major risks, any potential intolerable high residual risks, and material issues
- Estimates of resource requirements

- Key business drivers for the opportunity
- Project constraints identifications
- Geotechnical and Hydrology investigations
- Project objectives definition
- Strategic investment alternatives and source of investment
- Alignment of the investment with the business strategy
- Commercial terms such as NPV, IRR, BCR, …
- Strategic planning

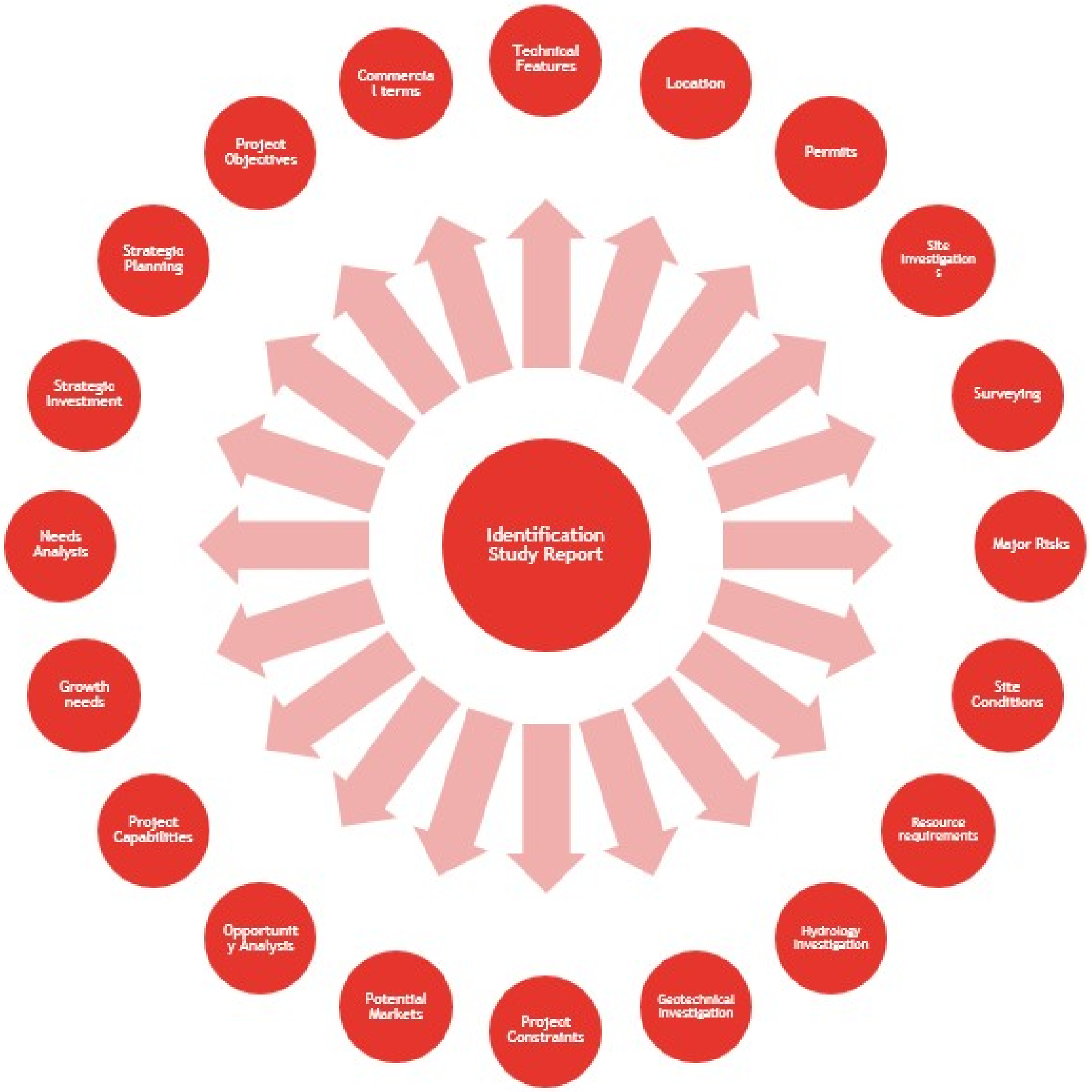


FIGURE 2-3 **Identification Study Report Components**

2.1.2 Selection Phase Study

The selection phase study has the greatest influence on the definition and execution phases. The purpose of this phase is to assess all reasonable value-creating alternatives and select the single most valuable investment alternative to be studied further and optimized in the definition phase. It shall generally comply with client standards, standard engineering practices and with the requirement set out in the contract framework. The project feasibility study consisting of financial, economic, market, risk, legal, environmental and technical characteristics are established during this phase to determine if the project provides value to the organisation [F.Lawrence Bennett, 2003].

Freezing the project scope at the conclusion of the selection phase enables engineering to proceed effectively in the definition phase. It is essential to ensure the technical and commercial viability of the selected project prior to further study and optimization in the definition phase. The key activities in this phase are but not limited to [Bhp PDM, 2011]:

- Completing opportunity framing and generating the list of alternatives to evaluate options for developing resources
- Commence the permitting process with engineering support
- Select a single configuration for the investment
- Develop a long-term whole of life asset management strategy
- Perform sufficient engineering to support selecting the preferred investment alternative
- Freeze the scope of the preferred investment alternative to enable successful unhindered progression to detail design in the definition phase
- Develop high level cost estimate for the selected project
- Establish master schedule for the preferred investment alternative
- Establish the need for pre-commitments of long lead items and timing to release
- Ensure a detailed PEP is in place including clear investment KPIs for any pre-commitments and early works
- Establish execution strategy including whether to use a project resource or award to implementation contractor to carry through execution
- Ensure an actionable bid is in place to award to the implementation contractor at the appropriate time
- Establish key members in the team using whenever possible experienced resources
- Determine study work plan for next phase including resources and services required to deliver the study
- Demonstrate a sound business case to support gating to next phase

When selecting the preferred project, net present value (NPV) incorporating risk/ uncertainty (considering the sensitivity analysis) is primarily applied as the key selection criteria. It has been determined that HSEC & sustainability ranking can be additionally included in this phase. For example, from the identified projects with the following specs in Table 2-1, Project F & H would be a preferred investment alternative to be progressed to definition phase due to the greater NPV and lower risks as shown in Figures 2-4 and 2-5) [Stoemmer P, 2009].

TABLE 2-1 Investment Alternatives

Project	Duration-Years	NPV- Million Dollars	Risk rate
A	3.4	$ 95	High
B	2.9	$ 146	Medium
C	2.5	$ 61	High
D	4.0	$ 117	Medium
E	3.8	$ 154	High
F	3.5	$ 163	Low
G	3.3	$ 77	Medium
H	3.8	$ 123	Low
I	2.6	$ 89	Low

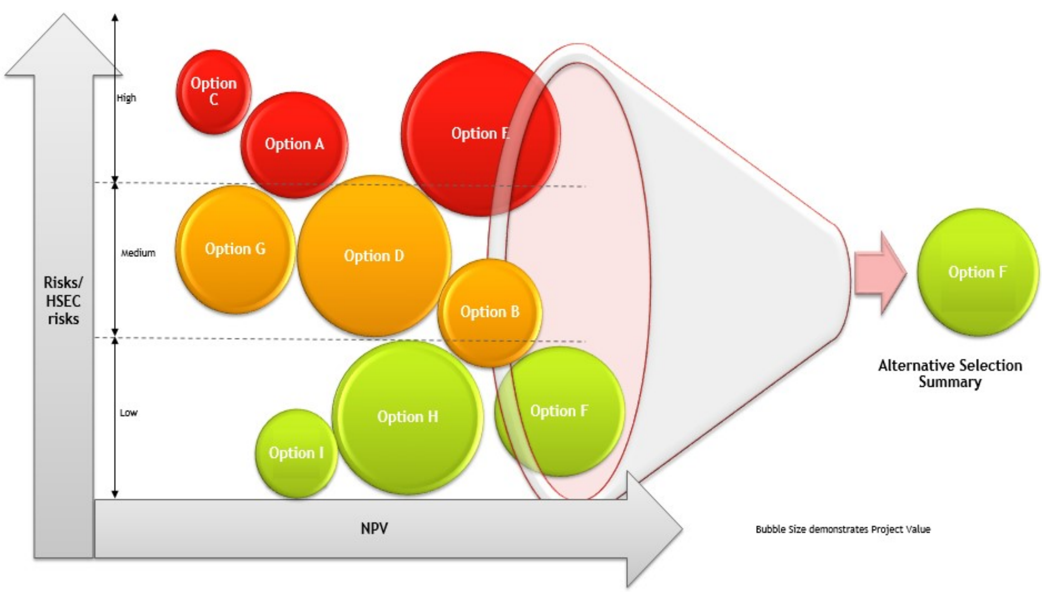


FIGURE 2-4 Alternative Selection Criteria

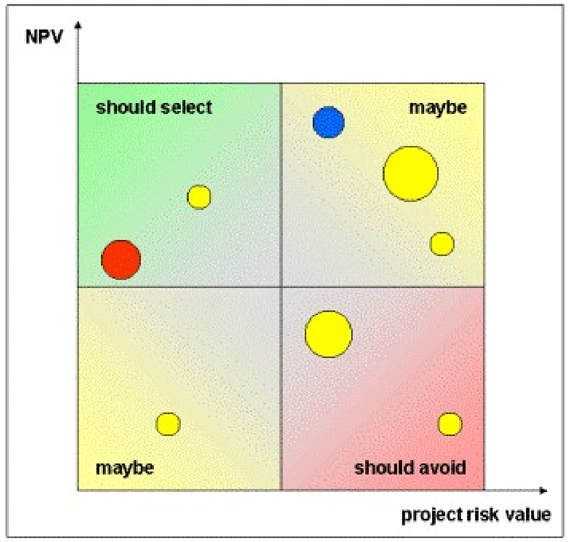


FIGURE 2-5 Comparative analysis example

2.1.3 Definition Phase Study

The definition phase study is the planning required for the transition to the execution phase. This phase includes detailed engineering, resource planning, Risk & HSEC planning, Schedule development & project cost estimates, construction selection, statutory approvals, project objective development, KPIs [Frigenti E. Comninos D, 2002], and Project Execution Plan. The purpose of this phase is to finalize and lock-in the project scope, schedule, budget, commercial terms and conditions and regulatory approvals and agreements prior to the execution phase. As illustrated in Figure 2-6, the key tasks in the definition phase are but not limited to [Bhp PDM, 2011]:

- Undertake sufficient engineering to support the development of master schedule and high-level cost estimates
- Develop contracting and procurement plans and ensure actionable bids are in place and ready for award
- Establish and agree the project execution plan
- Build the implementation contractor`s team
- Develop a detailed schedule for the execution phase
- Complete an environmental impact statement permitting process

- Update the business case to ensure the range of outcomes is quantified
- Tangibles define the scope, schedule, cost, and quality parameters of the project
- Assess the risk profile of the proposed project from a qualitative and quantitative perspectives
- Ensure operations have approved and signed off on the scope
- Ensure no residual or future issues could significantly impact the assessment set out in the definition study
- Define key performance indicators of the proposed project
- Confirm the asset management strategy and develop a comprehensive asset management plan
- Provide baseline for management, controls, monitoring and reporting of the proposed execution of the project
- Complete project study report including basic design of project and
- Finalize the investment evaluation model and provide required funds for the execution phase of the project.

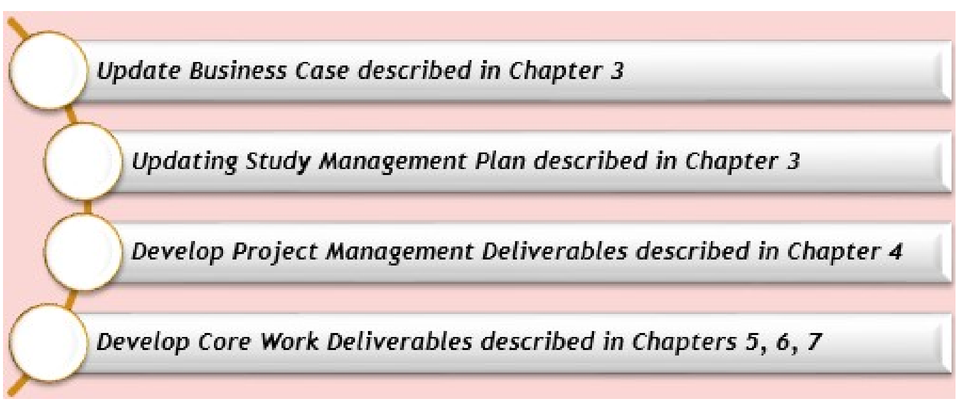


Figure 2-6 Critical key Tasks in Definition phase (Bhp PDM, 2011)

2.1.4 Execution Phase

The execution phase aims to deliver the agreed project objectives, scope of work, and approved execution phase key performance indicators (KPIs). Detailed engineering, contract awards, mobilization, bulk construction works, system completion, punch listing process, pre-commissioning, commissioning, start up, performance testing, and transition to operations are categorized in this phase. In the execution phase, the key tasks are to ensure [Bhp PDM, 2011]:

- Integration of the functions to create an effective project organization capable of delivering the project objectives
- Delivery of the project in accordance with the project execution plan, scope of work, schedule, budget, and quality
- Monitoring project performance against baselines and approved KPIs
- Project execution is controlled, monitored, and reported
- Change management is implemented
- Operations and commissioning teams are in place prior to the plant mechanical completion
- Operational readiness and transition to operations plans are in place
- Effective operator requirement and training programs are in place and
- Project lessons learned are populated for future references

2.1.5 Close up phase

The close up phase refers to the overall completion of the project. The processes also applies to each phase of project, work process, and contracts that encompasses all parts of project scope of work. The key objectives of the close-up are to ensure that [Mulcahy R, 2009]:

- Completion of project is documented
- All project agreements and contracts are closed
- The actual performance and project outcomes are documented and compared against project objectives and performance baselines

- Lessons learnt are documented and finalized
- The project is handed over to the subsequent life cycle phase or operations
- Project documentation is handed over and archived, and
- A comprehensive project close-out report is developed

2.2. Front End Loading

Front end loading is the process of undertaking sufficient detailed studies, design work, estimates and analysis associated with the project to minimize uncertainty and achieve a significant level of accuracy before a project is submitted for authorization. According to the Construction Industry Institute (CII), FEL is the process of developing sufficient strategic information with which Clients can address risk and make decisions to commit resources in order to maximise the potential for a successful project. It also referred to as pre-project planning, feasibility analysis, conceptual planning, programming/schematic design, and early project planning [Construction industry institute, 2012].

Benchmarking work indicates direct correlation between the quality of FEL tasks and the overall project success in terms of cost and schedule performance [Wang and Gibson Jr, 2012]. Benchmarking further aims to improve project definition and then there is an expectation that the project outcomes are delivered without further variations [Hollmann and John K, 2001].

Figure 2-7 demonstrates the importance and influence of the sufficient and quality FEL on the outcomes of the project [Weijde, 2008]. The higher the degree of FEL, the higher the value that can be extracted from the project. In this regard, the most value is generated in the early phases of the project development process, i.e. the identification and selection phases. There is also a subsequent fall off in the potential to create value in the later phases of development [Megginson, 2012].

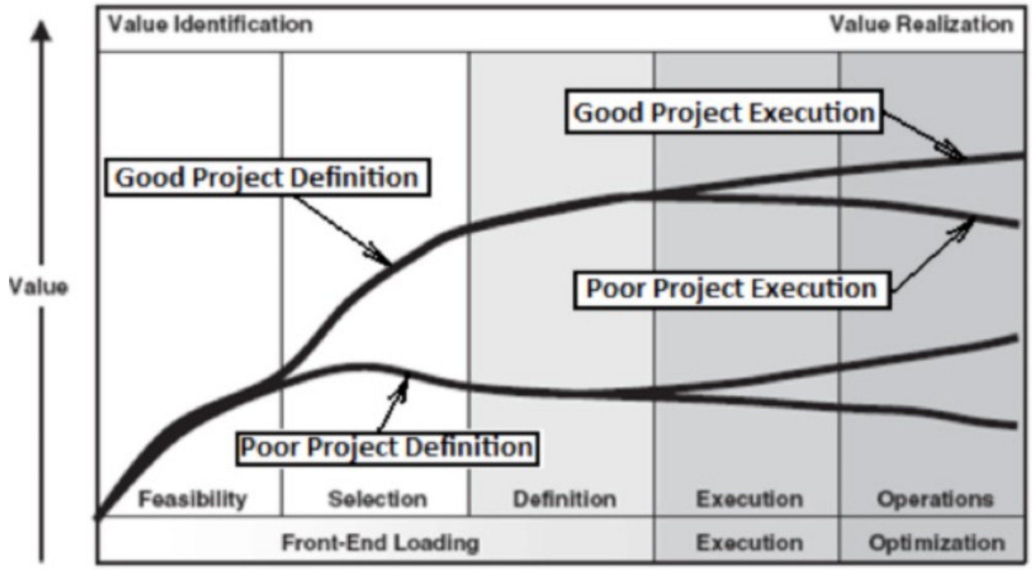


Figure 2-7 The value of front-end loading

2.3. Early Works and Pre-Commitments

Occasionally, some of the project components particularly specific Equipment/Materials follow a protracted process (including preparation of drawings, plant hire, approvals processes etc.) for obtainment, and in this regard, the project team requests approval for pre-commitment prior project sanction into execution phase. These pre-commitments during the study phase are primarily designed to mitigate project risks and accelerate the schedule. They can take the form of "long leads", bringing forward elements of the contracts and procurement program or "Early Works" which are effectively mini projects in advance of the core program. Whilst these activities enhance project performance, they do increase safety & deliver risk if the implementation impacts are not clearly recognized and carefully managed [DBW,2019].

Early works evidently brings an associated increase in project risk and exposure with construction activities on site. The implementation plan for these activities in the study phase includes an approved project execution plan consistent with the standard outlined in execution planning.

3. PROJECT BUSINESS CASE & STUDY DEVELOPMRNT

3.1. Project Study Development

Study management describes the overall governance for planning and control of the study phases (identification, selection, and definition). It focuses on the study planning process as well as the study work plan. The purpose of this chapter is to demonstrate a clear understanding of the purpose of the study, its objectives, scope of work, approach & methodology, required deliverables and to define the mandatory parameters of the project business case. The primary aim is for consultants, clients, EPC & EPCMs, and Engineering service providers to map their internal process and assess the quality of their deliverables at business case & study plan reports.

The study team observes the following principals while undertaking study management tasks [Bhp PDM, 2011]:

- Robust and comprehensive analysis of all potential alternatives. This is achieved if technical and economic parameters of an intended project have been thoroughly examined against predetermined criteria or agreed business objectives and stakeholder requirements
- Project scope of work development through the study phases
- The true measure of success of how deliverables meet the business objectives
- Deliverables development and documentation based on study work plan
- Integration management of all parts of studies
- Strategy & rules identification for managing pre-commitments to maintain the objectivity of the study work
- Study deliverables review on the completion of any aspect of the study phase

At first step, to develop a study work plan, the study team should review the statement of requirements, project documents, current investment case scope, and translates the project objectives into a set of study objectives that will derive the creation of the study scope of work and form the basis of evaluating successful completion. The study scope of work shall address all technical and commercial aspects to be prepared and shall identify key deliverables and processes for review. It is also critical to set agreed standards, scope boundaries, level of details, criteria, and level of confidence to be achieved for each work pack.

Once the key objectives and scope of the study have been fully documented, the project team develops a strategy for executing the study. The next step is to outline the governance arrangements including study organization structures that would best deliver the study scope of work. The roles of external parties, decision-making hierarchy, steering committee, boundaries of accountabilities, review process are the examples that shall be considered in the study governance. At this stage, the study team shall identify individuals, resources, sub consultants with the appropriate skills & experiences to undertake a role in the study organization of deliver a package of work. A plan to mobilize all key service providers and the duration of their assignment, clarification of roles and responsibilities of key personnel are also essential.

The project team then develops the relevant plans for all key technical functions as well as control & management functions. These plans also identify any procedures and systems required to execute the study and produce all required deliverables and the format, frequency and circulation of progress reports [Lock D, 2004].

While all required study deliverables are developed, the team

- Defines the responsibility matrix to ensure the allocation of roles to the relevant individuals
- Prepares detailed budget estimates with appropriate level of contingency with all other provisions to complete the full study scope
- Develops a study schedule including all key activities and required milestones.

Typical contents of the study work plan are as follows (Figure 3-1) [Bhp PDM, 2011]:

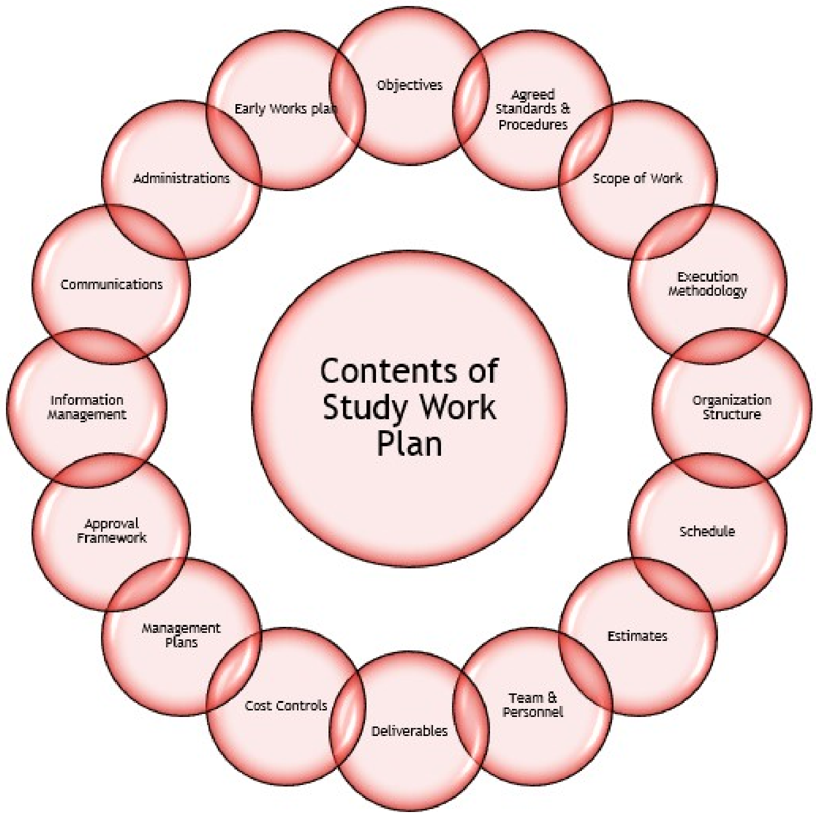


FIGURE 3-1 **Typical Contents of the Study Work Plan**

- Business objectives, Project objectives, and study objectives (e.g. Feasibility studies):
- Study agreed Standards and procedures
- Study scope of work
- Study execution methodology
- Study phase organization structure
- Study schedule, Project master schedule, and reporting procedure
- Study estimates (Study budget and potential project cost estimates)
- Team and personnel
- Deliverables (e.g. engineering deliverables, capital cost estimates, Master schedule, PEP, Scope of work, etc.)
- Study cost controls

- Management plans to manage various work packs and functional processes during execution phase of the project
- Approvals framework
- Information management including the capture and sharing of data, the ownership of intellectual properties, software licensing, office system & equipment, etc.
- Reporting and communication
- Administration including policies for traveling, insurance, accommodation, payments, etc.
- Pre commitments and early works that requires project execution plan to be followed

Once a study phase for a project has been authorized, the project team conducts the study in accordance with the approved strategy, budget and schedule and any requirements identified to meet the objectives, needs and expectations of stakeholders.

At this stage the current project business case, scope and deliverables should be periodically verified against the stakeholder requirements and strategic goals, which initially provided the basis for project initiation.

Following the above, a study report which is an overarching summary report that rolls up a range of specialized reports and plans to provide an integrated view of technical and economic viability of the opportunity as well as the recommendations and plans for next phase. The report provides a summary of findings by describing the key elements of the project. It also outlines the basis and development thereof, and the reasoning for the scope and approaches adopted. Overall summaries and strategies, technical info, market analysis, schedule, cost, and scope of work, risk management, HSEC, stakeholder management, study delivery, and investment evaluations (business case) are the main components of study report (Figure 3-2) [Lipton S, 2002].

The timeline required to complete the study reports at the end of each phase is a critical part of study schedule. Whilst individual sections are drafted progressively, the whole report is only finalized and compiled when all other work is completed.

FIGURE 3-2 **Typical Components of the Study Report**

3.2. Project Business Case Study

This section provides introductory information about decision-making process at identification/selection phases and main components of feasibility studies report. The purpose of the feasibility study is to investigate in detail whether the project is a desirable, viable and achievable investment.

Initially, the organization should conduct strategic planning to identify a set of possible projects to meet the end user`s specific defined needs. The strategic plan is sometimes referred to as an organization master plan, long-term expansion plan, strategic plan, or program-level plan. Potential projects are selected from the list of possible projects identified in the strategic plan and afterward feasibility studies are carried out to prioritize selected projects. The goals of maximizing public benefits [Thompson A, 2005] together with the financial indicators such as "Net present value" and "Internal rate of return" are generally the key factors to test suitability and the readiness of individual project for further development. The project feasibility study report should consist of the following analysis (Figure 3-3) [F.Lawrence Bennett, 2003]:

FIGURE 3-3 **Business Case Study Report**

- **Technical analysis:** sufficient technical studies such as field surveying, structural, geotechnical, hydrological, environmental conditions, drainage, preliminary design of facilities, preliminary scope definition, and other required studies as part of basic design must be undertaken to be able to prepare cost range for the potential projects [Tsimplokoukou K, Sfakianaki E, 2012]. High levels of risks as well as alternatives (different scenarios) shall be considered in the project preliminary cost estimate. Clear engineering aspects of the project (for example technical specification of required facilities), assessment of technical risks, scenarios of project size based on the market analysis, and the manageability of operational aspects of the projects are important in the technical analysis report. The proposed technical specs should offer at least rough estimates of cost to meet the projected demand, standards, and other objectives. The basic design will also assist the Sponsor in appraising proposals received later at the bidding stage.

- **Environmental impact analysis:** this can be stand- alone document or part of feasibility study report that describes [Subash S.M, Chandrabose K, 2013]:
    - The project geographic, ecological, social, and temporal context
    - The physical, biological, and socioeconomic conditions, including all changes anticipated before the project commences, within an area around the project site
    - Action causing physical changes in the locality, any use of natural resources, any use of harmful materials, release of pollutions to the air, ground and underground water, production of solid waste, generation of noise, heat, and vibration, risk of accidents, and details of environmentally sensitive area from project site
    - Exploration both opportunities and threat to the environment in quantitative terms and it`s mitigation plan
    - Management plan and monitoring program to be taken during the execution and operation phases to eliminate adverse impacts and reduce them to the acceptable levels
    - Relevant costs and benefits
    - Regulatory approvals and applying for environmental clearance

- **Financial Analysis:** this section is an important part of feasibility studies covers potential financial risks, identification of any financial supports from the government, any interested private partners, overall project cost including maintenance and operation costs, and assumption of income generation. The purpose of the financial assessment is to determine the payment required to ensure the project is considered attractive, particularly to the private sector. A typical financial analysis uses the following inputs [COMFAR III, 2007]:
    - Planning horizon, Project master schedule including operation phase
    - Project life-cycle costs including fixed investment costs and production costs
    - Cost Structure, for example, Capital cost (CAPEX) based on the component of preliminary technical design, and Operating & Maintenance costs (OPEX) based on lifetime schedule of project assets

- Depreciation schedule of physical assets
- Inflations and price escalations
- Income taxes, subsidiary, and allowance
- Financial risks
- The discount rates (or required rate of return)
- Joint venture partners and debt - equity of private sector investment
- Investment timing and lifetime
- Source of finance (long-term loans, short-term loans, foreign loan, and equity/risk capital)
- Working capitals
- Debt and repayment schedule
- Sales and production program
- The associated forecast revenue stream, and
- Ranges on assumptions to consider probable outcomes

The output of this module is a quantitative analysis that includes summary financial info, expected returns (NPV and IRR), sensitivity reports, cash deficit and an assessment of gap funding requirements.

The following key methods are utilised to prioritize and select multiple projects that can be applied in project financial analysis:

- **Net Present Value (NPV):** is the present value of the total income minus total costs over the project life cycle time. Usually projects with greatest NPV are selected. Also, Present Value (PV) is the value today of future cash flow and can be calculated as per below formula [Mulcahy R, 2009].

$$PV = \frac{FV}{(1 + r)^{n}}$$

Equation 3-1 Present Value- PV

Where Future Value (FV), internal rate (r), Number of accounting periods (n).

- **Internal Rate of Return (IRR):** is the rate at which project total costs and total income are equal. As shown at Figure 3-4, it gives percentage return at which the net present value of the project equals zero. Usually projects with greatest IRR are selected [Mulcahy R, 2009].

$$r = \left(\frac{FV}{PV}\right)^{\frac{1}{n}} - 1$$

EQUATION 3-2 INTERNAL RATE OF RETURN- IRR

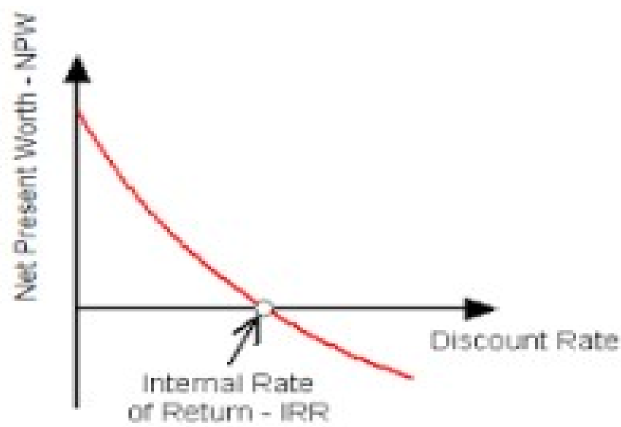


FIGURE 3-4 **IRR Concept**

- **Benefit Cost Ratio (BCR):** this ratio compares the benefits (not profit) to the cost of different options [Daniels RC,2015]. All benefits and costs should be expressed in the discounted present value. Projects with BCR more than 1 are selected:

$$BCR = \frac{PV_{benefits}}{PV_{costs}}$$

where:

$PV_{benefits}$ = present value of benefits

PV_{costs} = present value of costs

EQUATION 3-3 **Benefit Cost Ratio- BCR**

- **Payback Period (PP)**: is the number of time periods it takes to recover project investment before start of accumulating profits. Projects with shorter payback periods are selected [Stoemmer P, 2009].

$$\text{Payback Period} = \frac{\text{Total cash out}}{\text{Average per period cash in}}$$

Equation 3-4 Payback Period- PP

- **Opportunity Cost (OC):** Refers to the opportunity given up by selecting one project over another project [Mulcahy R, 2009]. For example, in comparison of two projects, Project A with NPV 487 million dollars and project B with NPV 350 million dollars, opportunity costs of selecting project A would be 350 million dollars.

- **Economic Value Added (EVA):** is the amount of added value the project produces for the company`s shareholders above the cost of financing the project [Haridy H, 2016]. It concerns with whether the project returns to the company more value than it costs.

Below is an example of calculating financial parameters for sample EPCM project with the following assumptions as shown at Table 3-1.

Table 3-1 EPCM project- Financial estimates

Project Costs (Million dollars)		
* Study phase- Engineering & Procurement	$ 165	1.5 Years
* Execution phase- Fabrication, Construction, and Commissioning	$ 720	3 Years
* Production phase /Year	$ 20	6 Years
Income/Year (Million dollars)	$ 315	6 Years
Discount Rate	4.50%	

Based on the above data, project total investment cost/income is equal to:

Total Cost (million dollars): 165 + 720 + 20 * 6 = 1,005

Total Income (million dollars): 315 * 6 = 1,890

Future cash shall be converted to today`s value, therefore with consideration of 4.5 % discount rate, present value for each year will be calculated as shown at Table 2-2.

Table 3-2 Project Net Present Value (NPV)

Cash Flows	Study Phase		Construction Phase			Production Phase					
	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Costs- Cash out	-$ 25	-$ 140	-$ 180	-$ 330	-$ 210	-$ 20	-$ 20	-$ 20	-$ 20	-$ 20	-$ 20
Income- Cash In	$ -	$ -	$ -	$ -	$ -	$ 315	$ 315	$ 315	$ 315	$ 315	$ 315
Total Cash Flow	-$ 25	-$ 140	-$ 180	-$ 330	-$ 210	$ 295	$ 295	$ 295	$ 295	$ 295	$ 295
Present Value- Cash Out	-$ 25	-$ 134	-$ 165	-$ 289	-$ 176	-$ 16	-$ 15	-$ 15	-$ 14	-$ 13	-$ 13
Present Value- Cash In	$ -	$ -	$ -	$ -	$ -	$ 253	$ 242	$ 231	$ 222	$ 212	$ 203
Present Value- Total	-$ 25	-$ 134	-$ 165	-$ 289	-$ 176	$ 237	$ 227	$ 217	$ 207	$ 199	$ 190
Cum. Present Value	-$ 25	-$ 159	-$ 324	-$ 613	-$ 789	-$ 552	-$ 326	-$ 109	$ 98	$ 297	$ 487

Net Present Value

In order to compute NPV, total discounted costs shall be deducted from total discounted income over the project life cycle (10.5 years) which is equal to 487 million dollars. Cumulative present value as shown in Figure 3-5 is equal to project NPV.

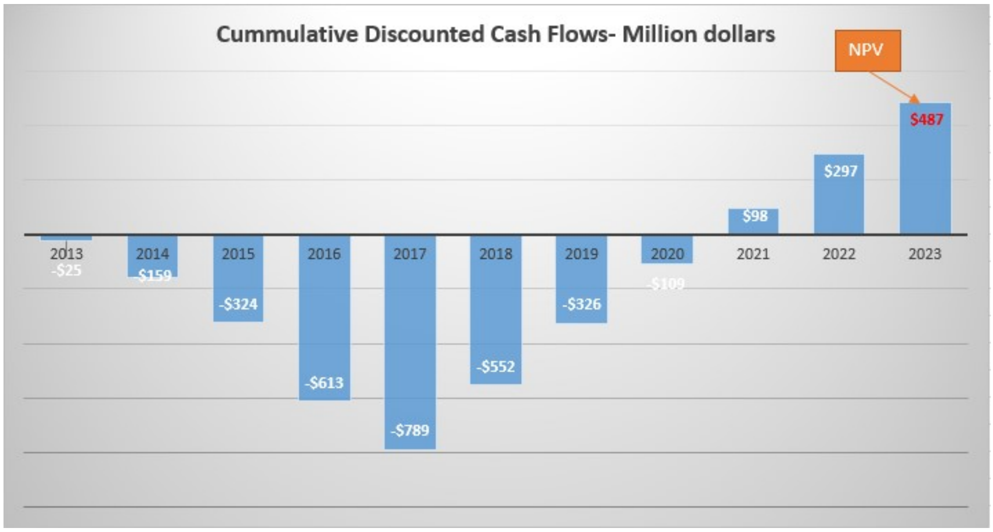


Figure 3-5 Discounted Cash Flow

As per below calculation shown at Table 3-3, discounting 15.74% gives NPV of 0. It means that if the IRR (15.74%) is greater than company`s required return (e.g. 12%), the project will be attractive to invest in the subsequent phase. The IRR method is ineffective for projects with multiple positive & negative cash flows.

TABLE 3-3 EPCM PROJECT- IRR

Discount Rate	15.74%											
Cash Flows		Study Phase		Construction Phase			Production Phase					
		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Costs- Cash out		-$ 25	-$ 140	-$ 180	-$ 330	-$ 210	-$ 20	-$ 20	-$ 20	-$ 20	-$ 20	-$ 20
Income- Cash In		$-	$ -	$ -	$ -	$ -	$ 315	$ 315	$ 315	$ 315	$ 315	$ 315
Total Cash Flow		-$ 25	-$ 140	-$ 180	-$ 330	-$ 210	$ 295	$ 295	$ 295	$ 295	$ 295	$ 295
Present Value- Cash Out		-$ 25	-$ 121	-$ 134	-$ 213	-$ 117	-$ 10	-$ 8	-$ 7	-$ 6	-$ 5	-$ 5
Present Value- Cash In		$-	$ -	$ -	$ -	$ -	$ 152	$ 131	$ 113	$ 98	$ 85	$ 73
Present Value- Total		-$ 25	-$ 121	-$ 134	-$ 213	-$ 117	$ 142	$ 123	$ 106	$ 92	$ 79	$ 68
Cum. Present Value		-$ 25	-$ 146	-$ 280	-$ 493	-$ 610	-$ 468	-$ 345	-$ 239	-$ 148	-$ 69	-$ 0

Internal Rate of Return (IRR)

Net Present Value

The BCR is also a useful measure as it allows many projects to be ranked. It attempts to summarize the overall value for money of a project or proposal. As shown at Table 3-4, discounted cash in (1,362) and cash out (876) shall be used to compute BCR.

BCR = Discounted Cash in (1,362)/Discounted Cash out (876) = 1.556

TABLE 3-4 EPCM PROJECT- BCR

Cash Flows	Study Phase		Construction Phase			Production Phase					
	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Costs- Cash out	-$ 25	-$ 140	-$ 180	-$ 330	-$ 210	-$ 20	-$ 20	-$ 20	-$ 20	-$ 20	-$ 20
Income- Cash In	$-	$ -	$ -	$ -	$ -	$ 315	$ 315	$ 315	$ 315	$ 315	$ 315
Total Cash Flow	-$ 25	-$ 140	-$ 180	-$ 330	-$ 210	$ 295	$ 295	$ 295	$ 295	$ 295	$ 295
Present Value- Cash Out	-$ 25	-$ 134	-$ 165	-$ 289	-$ 176	-$ 16	-$ 15	-$ 15	-$ 14	-$ 13	-$ 13
Present Value- Cash In	$-	$ -	$ -	$ -	$ -	$ 253	$ 242	$ 231	$ 222	$ 212	$ 203
Present Value- Total	-$ 25	-$ 134	-$ 165	-$ 289	-$ 176	$ 237	$ 227	$ 217	$ 207	$ 199	$ 190
Cum. Present Value	-$ 25	-$ 159	-$ 324	-$ 613	-$ 789	-$ 552	-$ 326	-$ 109	$ 98	$ 297	$ 487

PV- Cost: 876

PV- Benefit: 1,362

Net Present Value

Using the method of payback period (PP) provides investors the simplest approach. We decide in favour of the project with the shorter payback period. To compute the PP, "project total costs (cash out)" and "average income (cash in) per period" are required as demonstrated at Table 3-5.

PP = Total Cash out (1,005)/Average Cash in (172) = 5.9 years

TABLE 3-5 EPCM PROJECT- PP

Cash Flows	Study Phase		Construction Phase			Production Phase					
	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Costs- Cash out	-$ 25	-$ 140	-$ 180	-$ 330	-$ 210	-$ 20	-$ 20	-$ 20	-$ 20	-$ 20	-$ 20
Income- Cash In	$-	$ -	$ -	$ -	$ -	$ 315	$ 315	$ 315	$ 315	$ 315	$ 315
Total Cash Flow	-$ 25	-$ 140	-$ 180	-$ 330	-$ 210	$ 295	$ 295	$ 295	$ 295	$ 295	$ 295
Present Value- Cash Out	-$ 25	-$ 134	-$ 165	-$ 289	-$ 176	-$ 16	-$ 15	-$ 15	-$ 14	-$ 13	-$ 13
Present Value- Cash In	$-	$ -	$ -	$ -	$ -	$ 253	$ 242	$ 231	$ 222	$ 212	$ 203
Present Value- Total	-$ 25	-$ 134	-$ 165	-$ 289	-$ 176	$ 237	$ 227	$ 217	$ 207	$ 199	$ 190
Cum. Present Value	-$ 25	-$ 159	-$ 324	-$ 613	-$ 789	-$ 552	-$ 326	-$ 109	$ 98	$ 297	$ 487

Total Cost (Cash out): 1,005

Average Income (Cash in): 172

In a recession, at times, the selling price (income) may be lower than expected or due to inflationary factors, the project costs may be higher than the original estimates. Therefore, it is essential to consider price deviations (various scenarios) in the financial studies to ensure the project is still feasible. Figure 3-6 demonstrates NPV sensitivity analysis graph for both potential Income & Cost deviation. For example, at 10% less sale (income), NPV of 351 million dollars will be expected and at 35.7% less sale, project will not be feasible to execute.

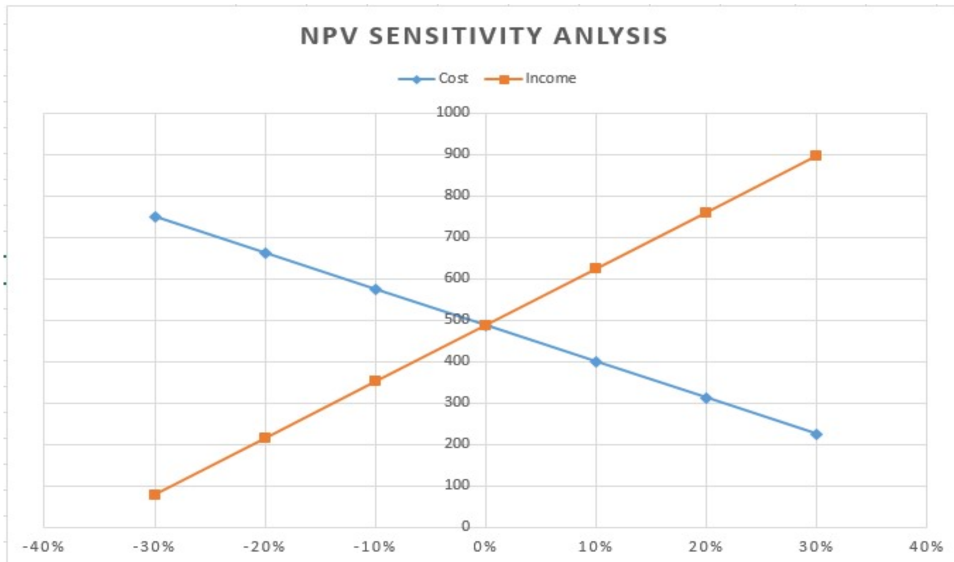


Figure 3-6 EPCM project- NPV Sensitivity Analysis

- **Economic Analysis:** the purpose of economic analysis is to determine whether there is an economic benefit for the investment decision. The results of the market analysis and scope, technical, social, and environmental feasibility, financial cost assessments, and risk analyses are all inputs to the economic feasibility. Direct & indirect employment effect within the project, any future economic impacts and benefits, market valuations of the land, materials, and labours, the value of services that end users are willing to pay, and economic added value are the key factors in this module. The typical out-put of the economic assessment are [Subash S.M, Chandrabose K, 2013]:
  - Value-added report (tax and subsidies, gross domestic value added, net domestic value added, net national value added, distribution of value added, and present value)
  - Employment effects
  - Economic appraisal (benefit-cost analysis including financial value and taxes, adjusted market value, foreign exchange adjustment, economic value, and present value info)

- Net foreign exchange effect, and
- Sensitivity report for different set of scenarios and identify desired NPV & IRR

- **Market Analysis:** the market analysis provides an important basis for determining the project scope and scale of outputs. This module includes investigation of target users, level and quality of existing services, needs analysis, clarification of the various options to meet the service need, demand assessment and expected growth over project life cycle, definition of basic parameters of project outputs [Soota T, 2005].

  The demand assessment is a critical factor in the technical sizing of the project, financial viability and economic analysis. The result of the market and demand analysis will be a range of options for the level of service based on the potential size of the market. Based on this, scenarios of project size can be developed with associated technical parameters. Hence, the market analysis may lead to a refinement of the definition and scope of the project.

- **Social Impact Analysis:** Infrastructure projects usually have significant both positive and negative social impacts arising from their construction and operational phases. Requirement for the resettlement and impact on the people`s quality of life is an example of social impacts on communities. This process requires the incorporation of a wide range of key stakeholders to identify social issues and provides a framework to gather and analyse social data feeding into design and delivery of the project. The social impacts originated from the defined project can be on individuals, group of people, organizations, or even national and international political and legal systems. The stages in a Social Impact Assessment are [Dept. of Economic Affairs, Ministry of Finance India, PPP Toolkit, 2011]:
  - Describe the relevant human environment/ area of influence and baseline conditions
  - Develop an effective public plan to involve all potentially affected public
  - Describe the proposed action or policy change and reasonable alternatives
  - Scoping to identify the full range of probable social impacts
  - Screening to determine the boundaries of the SIA
  - Predicting Responses to Impacts Develop Monitoring Plan & Mitigation Measures

- **Risk Studies:** The project feasibility study should contain all high level identified risks associated with the project, risk management strategy, risk planning and assessment, rough schedule & cost contingencies, and the risk owner. It is important to determine which party will take the responsibility of each risk and to identify the best option to eliminate, minimize, transfer, or share the probability & impacts of the project risks. The goal of this module should be to reduce project overall risks as much as possible. Full risk management usually would be carried out at the end of definition phase and before contract award sign-off. Design, Financial, payment, planning & project management, technical & technology, approvals, delays, site, construction, operations, changes in law, estimating, and other risks are example of risks categorizations that needs to be taken into account at project risk registers [Baccarini D, Archer R,2001].

4. ROJECT MANAGEMENT DELIVEABLES

4.1. Project Management Function

Project management competencies, disciplines, activities, and processes are considered the key success drivers for all projects. This chapter's objective is to identify the project management key deliverables at the study phase of typical construction projects. These goals are summarised in the below objectives [Lessard C. Lessard J.,2007]:

- To outline accurate processes that ensure a project's scope is accurately defined and mapped, it is critical that the project team only allocate the right amount of work necessary to successfully complete a project (and ensure all stakeholders are only concerned with controlling what is and what is not part of the project's scope). The main concern is to avoid any ambiguity, incomplete definition, transience, and uncollaborative scope. Many construction projects still suffer from unnecessary works, scope creep, misinterpretations in requirements and design, schedule slippage & cost overrun due to incomplete and ineffective scope studies [GHD. PPM Sec 02, 2011].

- To increase efficiencies and productivity by applying effective time management principles that involve skills such as planning, setting goals and prioritizing for higher performance.

- To set a baseline for project expected costs and take actions to ensure the project is on budget. It also allows a business to predict impending expenditures to help reduce the risk of exceeding budget.

- To improve the quality of the services and products with respect to customer satisfaction, high accuracy, and compliance with applicable standards.

- To encompass the potential problems and risks before they occur and to mitigate the adverse impacts on achieving objectives. Risk analysis at the study phase is almost neglected in most construction companies and stipulations are generally not evident in the contract provisions.

- To set a standard for an efficient and effective process to manage the contract and suppliers. Companies must implement and maintain an organized contract management process to mitigate the risks associated with contract.

- To define a clear methodology to manage project stakeholders and communications.

The project manager is responsible for managing the project processes and ensuring the correct tools and techniques are applied to successfully deliver the required measurable outcomes through all phases of the project life cycle. Project management function includes the processes for initiating, planning, executing, monitoring & controlling, and closing of each project phase.

The project management function is responsible for ensuring that the following areas are addressed [Vargas R, 2008]:

- Scope management, including clearly defining and controlling only the work required to complete approved scope
- Time management, including estimating the duration of activities, preparing a schedule, monitoring, and controlling deviations from the schedule
- Cost management, including resource planning, cost estimating, cost budgeting and cost control
- Quality management, including measuring overall performance, monitoring project results, and comparing to quality standards set out in the project planning process
- Human resource management, including organizational planning, staff acquisition and team development on a project specific basis
- HSEC management, including compliance with all statutory, client and company`s requirements

The project management plan will develop plans for each of the key tasks outlined above. These management plans will be detailed in the Project Execution Plan. It is also the responsibility of the project management function to ensure that the following principles, where applicable, are identified, documented, and clearly addressed and the necessary measures and planning are in place [Oberlender G, 2000]:

- All project members and stakeholders are aligned to the business objectives project goals and values to which the project is being delivered
- Collaboration within the team to ensure they are aligned and integrate effectively for the common purpose of the project
- Expectations and goals are clearly communicated to each of the team members
- A communication plan is agreed at the commencement of each phase of the project. And

Stakeholders are always informed of development status. Consistent, concise, and unambiguous communication will be a key focus for each project team through each phase of the project

- There is clear accountability identified at the commencement of each phase throughout the project and is reinforced in a consistent manner
- Retention of key staff across all phases of a project will support successful project outcomes. The aim is to identify the right people early and involve them in the project's development
- The level of engineering during the study phases will be well thought out and have the appropriate level of accuracy for obtaining client`s approval of funds. There is an expectation that those outcomes will be clearly defined and can be delivered without significant further change
- A process of regular independent reviews will be held at key stages during the project life cycle. The project management function will ensure the "right" expertise is identified and engaged to participate in these reviews
- An up to date risk management plan will be prepared and will be reviewed and updated at regular intervals
- The processes to support the planning, managing, controlling, and reporting on the delivery of a project, on time, on budget and according with the required quality and technical specification are in place and clearly understood by the project team.

Project management processes for the execution phase is to ensure the project is executed in accordance with the approved project execution plan and budget to meet the specific project objectives, agreed scope and project KPIs.

There are several distinct stages during execution that the project management function has overall responsibility:

- Setup and mobilization of project teams, contractors, systems and procedures, project, and construction offices
- The execution, management and controlling of and reporting on the core work processes
- Commissioning and handover to operations, and

- Closure of the project

Project management in the Execution Phase [Westland J, 2006]:

- The implementation of the project as approved in the project execution plan
- Monitoring overall project performance on a regular basis, to provide confidence that the project will satisfy the relevant quality standards as defined in the quality assurance management plan
- Ensuring information is made available to all project stakeholders in a timely manner
- Participate in client`s tender process, and
- Ensure the approved contract administration processes are in place & implemented

At completion of the implementation, commissioning and handover ensure that the approved close out processes are completed. This includes:

- Completion and settlement of the contract including resolution of any unresolved items, completion and sign off contract closeout documentation, and
- Gather and document all information to allow for administrative closure of the project. This includes a project evaluation and compiling lessons learned for use in planning future projects

4.2. Scope Definition

Scope management is the process of identification of all the works required to complete the project successfully [Passenheim O, 2009]. Requirement management plan, scope management plan, statement of requirement, requirement traceability matrix, project scope of work, and work breakdown structure are the main deliverables at scope management process as shown in Figure 4-1 [PMBOK Guide Fifth Edition, 2013].

Figure 4-1 Scope Management Deliverables

4.2.1 Requirement Work Plan

Requirements are the quantified needs and expectations of all stakeholders and are the foundation of project work breakdown structure. It begins with analysis of info from stakeholder's register and can be classified as business requirements, stakeholder requirements, functional & non-functional requirements, transition requirements, quality requirements, and project requirements.

Requirement work plan (RWP) shall be required to describe how requirements are planned and managed, how changes to the product will be managed and its impacts are analysed, and to determine traceability structure, metrics, and requirement prioritization process [Zambruski M, 2009].

4.2.2 Scope Plan

Project scope is a detailed description of project and product. It describes project boundary as well as final requirements of the project and is critical for project success. This document builds upon the project major deliverables, assumptions, constraints, project exclusions, and acceptance criteria [Jonasson H, 2008].

Project scope of work is derived from statement of requirement document and is the key input to the project execution plan.

Scope management plan is a guideline on how scope will be prepared, analysed, and controlled throughout the project. This document also describes the creation of detailed scope statement and work breakdown structure, how to maintain WBS, how to obtain formal acceptance of completed deliverables, and how to proceed changes to the detailed scope [Vargas R, 2008].

4.2.3 Statement of Requirements

A statement of requirements is the key input to the scope of work document and is a complete, clear, and unambiguous statement of project requirements, stated in the language of the key stakeholders in measurable terms. This document provides alignment of business and stakeholders needs with project deliverables, reducing changes due to possible misinterpretation. It further aims to improve the quality of the project deliverables, manage cost and time by significantly lowering the risk of reworking, and finally provide a baseline for project scope of work definition.

According to [Heldman K, 2002], all the project requirements shall be specific, measurable, achievable, relevant, and time limited [S.M.A.R.T].

4.2.4 Requirement Traceability Matrix

This document is a matrix that connects product requirements to the relevant deliverables and is good to track requirements throughout the project life cycle. It helps to manage changes to the product scope and contains source, owner, version, priority, complexity, acceptance criteria, and the status of each requirement [Roberson S. 1996].

4.2.5 Scope of Work

Scope of Work (SOW) is a complete and clear statement of project deliverables and detail description of the work required to be performed to achieve those deliverables [Jonasson H, 2008]. It is a fundamental basis to verify and control the scope during the execution phase. It also provides a quantified baseline to enable schedule development, cost estimating, and change control. Decomposition of project scope by WBS, OBS, and CBS are derived from this document.

According to [Uppal C,2002] the scope of work documentation for executing a project should be expressed in terms of the following four descriptive areas:

- Functional scope: for instance, the product to be manufactured or the amount of capacity to be provided
- Technical scope: the design philosophy, design standards and specifications to be used, as well as the process design to be adopted
- Physical scope: for instance, what structures will be (or will remain) standing in place after the project is completed
- Activity scope: the division and extent of responsibility among all the entities doing the work (for example, a statement that hookup is included, but commissioning is not included, in the scope of work)

4.2.6 Work Breakdown Structure (WBS)

WBS is a top-down hierarchical breakdown of the project scope into the deliverables and logically structured by areas, facilities, and systems. It provides a clear, consistent, logical, and deliverable oriented roadmap of the project scope through the phases, which enables the project to be scoped and effectively controlled. The WBS reflects the project scope in graphical outline, provides a framework for planning, executing, and controlling of works, defines a hierarchy of deliverables, provides basis for cost estimates, facilitates assignment of resources, provides a basis for battery limits, enables generating schedule activities, enables comparison of actual vs. budget, vs forecasts in relation to cost and time parameters, and provides cost and schedule performance assessment and effective monitoring and controlling process [Kerzner H, 2009].

The code of account contrasts to the WBS as it indicates the breakdown of commodities into the lower level of detail and is primarily used to cost controls and to roll up estimates, costs, and schedule resource loading.

Package breakdown structure differs to WBS as it represents how project scope aligns with the execution strategy and relates to procurement & contracting strategies. It is a breakdown of the project scope in terms of purchase orders, service orders, contracts, and technical service agreements. Both WBS and PBS are essential for planning, executing, controlling, and reporting [Miller D, 2009].

4.2.7 WBS Dictionary

WBS dictionary is a document that provides detailed information about deliverables, activities, and schedule data for each component of WBS. It includes WBS id, description of works, associated tasks, required resource, responsible person, schedule data, constraints, assumptions, technical references, milestones, quality requirements, and cost estimates [Heldman K, 2002].

4.3. Schedule Development

Scheduling is the detailed sequencing of tasks, assignment of logical relationships between tasks, allocation of resources, and duration estimates. Resource assignments may require re-evaluation of the activity duration, possibly changing the critical path and the completion dates. The project schedule is one of the key project management deliverables that will be used to manage project time. It is a plan for completion of the project based on the logical arrangement of activities, resource available, imposed constraint, and funding budget. To develop project schedule, following data are required:

- Scope of work and work packages
- Work breakdown structure and WBS dictionary
- Schedule template & procedures
- Contracts
- Contract & Procurement strategy
- Drawings, area plan, and specifications
- Quantities and BOM
- Resource availability, Resource Calendar, and resource usage maximum limits
- Milestones, constraints, and statuary approval requirements
- Any planned sequence, construction & commissioning methodology
- Calendars, working and non-working days

- Industrial regulations

As shown in Figure 4-2 following key deliverables shall be developed under the project time estimating process [PMBOK Guide Fifth Edition, 2013].

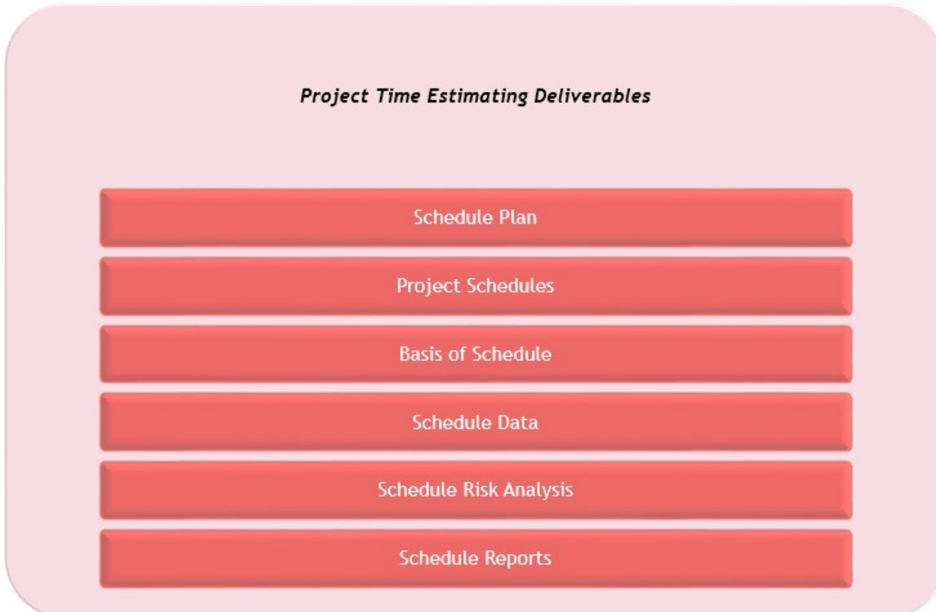


Figure 4-2 Time Estimating Deliverables

4.3.1 Schedule Management Plan

This document describes the process of developing schedule, and how to plan, control, execute, and manage the project schedule. The key components of a schedule management plan (SMP) are: schedule reporting format, performance measurement rules, schedule updating & maintenance, level of accuracy, tools & method to be used in schedule creation, threshold controls, and schedule contingency assessments, progress measurement, rules for resource levelling, float analysis method, variance analysis rules, method of progress S-curve development, schedule cash flow, scheduled budget forecasts, dependency types & allowed lead & lags, and instruction for schedule health checks [Carson C.W., 2011].

4.3.2 Project Master Schedule

The project master schedule illustrates the timeline of the overall project from the initiation phase through to project completion. It includes major milestones, high-level activities of engineering, procurement, construction, and commissioning, high-level pre-commitments tasks, and approval process. The purpose of the master schedule is to guide the development and execution of the project in accordance with the project execution strategy. This document can be used for extracting status reports, work coordination, resource control, time control and forecasting.

The effort required to prepare a schedule is dependent on the amount of project information available, the technical complexity of the project, the level of external and internal integration, and the level and definition of the scope.

The number of activities in project master schedule is contingent on the nature, duration, size, and complexity of project. Too much detail in schedule results in spending most time managing data and little time in understanding the progress, constraints, challenges to manage, and opportunities to exploit. The level of detail in the master schedule refers to the hierarchical display of the activities. At least four levels schedule type can be expected in the reports [PMI-Practice Standard for Scheduling, 2011]:

- Management level schedule (L1) is presented as a bar chart and shows overall timing of all aspects of the project
- Project level schedule (L2) shows critical path for the project and typically contains the key activities & milestones, engineering by discipline, procurement, key deliveries, construction by commodities, and commissioning activities by facilities. Various layouts of this schedule can be used in monthly reports
- Control level schedule (L3) shows detailed timing of all of activities on the project. It shows critical path and includes details of resources needed to undertake that element of work. It covers all engineering, procurement, construction, pre-commissioning, commissioning, and ramp-up activities. Generally, it is prepared to communicate the execution of the deliverables for each of the contracting parties. What-if scenario schedules are prepared at this level as mitigation alternatives for recovery
- Contractors schedule (L4) is to communicate the production of the work packs at the deliverable level. Construction contractors performing the work produce these schedules

often. It usually provides enough detail to plan and coordinate contractors or multi-discipline activities

During scheduling development, in particular at the execution phase, information such as crew size, labour count, production rates and equipment are considered when developing the relevant activity durations. Usually clear descriptions regarding the requirements for resource, labour and equipment loading are incorporated into the basis of schedule document.

4.3.3 Basis of Schedule

This document details the assumptions, known risks and structure that support the development of the execution phase schedule [Ronald J. Rider, 2015]. It serves as the mechanism to translate the underlying planning principles and assumptions into the execution phase schedule. Following are the component of the BOS [AACE,2009]:

- Terminology and glossary
- Key drivers
- A brief description of project objectives, scope, and execution plan
- Schedule assumptions
- Pre-commitments, and long lead items
- Critical path and near critical path description and logic analysis
- Method of calculations for activity duration
- Activity coding structure and definition
- Key milestones list and schedule KPI
- Calendars and non-working days
- Constraint list
- Sourcing and availability of labour and non-labour resources
- Accommodation strategy
- Brief description of contract & procurement strategy

- Internal and external interfaces including approvals
- planned curves
- Project risks, uncertainties, and opportunities
- Project benchmark comparisons with similar projects
- Issues & concerns, exceptions, and baseline changes & reconciliation [H. Lance Stephenson, 2007]

4.3.4 Schedule Data

Schedule data is the collection of info utilised to control the schedule. Following are the sub-deliverables of the project schedule as shown in Figure 4-3 [PMBOK Guide Fifth Edition, 2013]:

Figure 4-3 Schedule Data

- **Baseline schedule** or approved version of study schedules, execution schedule or project master schedule that can be used to track the actuals against it
- **Schedule presentations** such as bar charts, milestone charts, network diagrams, and other schedule reporting layouts
- **Project calendars** includes working days and shifts available for schedule activities

- **Resource histograms** or project resource requirements by time, resourcing curves, and commodity curves [Horluck J, 2009]
- **Cash flow** or project budget requirements by time, and budgeted cost of work schedule curve
- **What if schedules** to determine best scenario usually for delay recovery purposes
- **Planned progress data** both in time phased and cumulative format (S-curve)
- **Schedule contingency reserve** calculated from the impact of identified risks in the schedule

4.3.5 Schedule Risk Analysis

Schedule risk analysis is the systematic evaluation of identified risks and uncertainties associated with the activities included in the schedule. These uncertainties are the result of outcomes of threats and opportunities that a project can encounter during its execution. The main objective of schedule risk analysis is to determine:

- schedule contingency reserves (time buffer)
- schedule key performance index (KPI)

The above parameters will be developed by quantitative analysis (usually Monte Carlo simulation), once the schedule contingency is calculated, its impact is considered in the capital cost risk analysis.

The identified risks that the schedule exposed to include:

- specific activity risks which are those associated with the nature and characteristics of an activity or group of activities i.e. equipment delivery, fabrication shop availability, and
- general project wide risks that may affects the project as a whole, i.e. labour availability, weather conditions

According to the [Bhp PDM,2011] procedure, the schedule contingency is the length of time between the deterministic project completion date and the target date (KPI) as illustrated in Figure 4-4. The contingency reserve is a function of several factors including duration ranges, probabilistic distribution function, and the correlation of activities. Once the validity of schedule contingency reserves is assessed and finalized, the baseline schedule is established by adding this time buffer to the deterministic schedule.

For unknown risks, an amount of project duration (management reserves) for management control purposes is specified for unforeseen works within the scope of project. It is not included in the baseline schedule but is part of overall project duration requirements. Use of management reserves may require a change to schedule baseline.

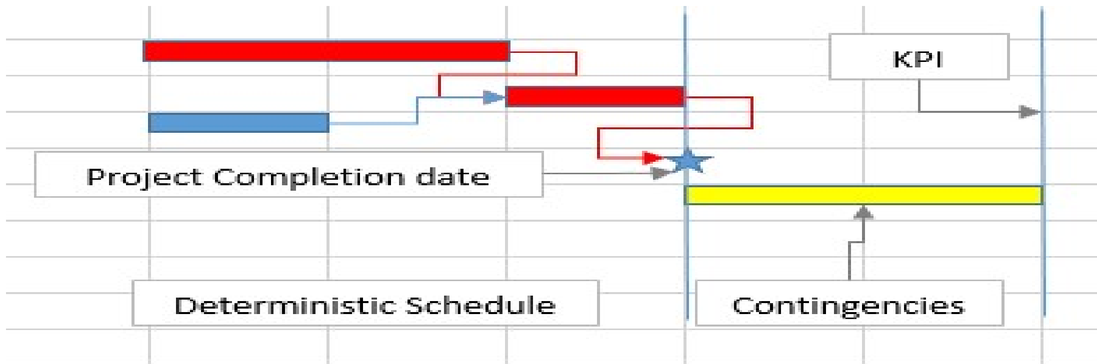


Figure 4-4 Schedule Contingencies

4.3.6 Schedule Reporting Outputs

The following outputs can be extracted from the approved schedule analysis at the initiation stage of a project [PMI- Practice Standard for Scheduling, 2011]:

- Overall schedule baseline based on the client requested pro forma/format
- Schedule risk analysis report including the probability of project completion date, margin acceptable dates for project planning (date range between optimistic and pessimistic dates), thresholds, duration sensitivity, critically Index, schedule sensitivity Index, and schedule duration contingencies [C.Maunder, 2009]
- Project milestone list
- Project area control level schedules organized by project phase, package, and facility)
- Project constraint list
- Critical & near critical path report grouped by project phases
- Area accommodation demands and availability

- Time based major commodity quantity report, earthworks, concrete, steel, cable, and…
- Engineering deliverables plan by IFT, AFC and by discipline
- Engineering baseline hours summary table organized by facility, discipline
- Engineering discipline early & late plan curves including recruitment, and availability
- Engineering early & late progress curves
- Contract & procurement progress curves
- Construction baseline quantities & hours summary table organized by facility, major commodity, and separable portions
- Construction major commodity progress curves, labour histograms, major equipment histograms.
- Construction project area summary report by facility
- Commissioning & ramp up labour hours and progress curves
- Weighting structure report
- Management level summary report including summary schedule data, key milestones, project progress curves, and summary risk data

4.4. Cost Estimating

The decision whether to proceed with an investment opportunity is driven by the potential value of the investment and its strategic fit. The value of investment is directly related to the cost of project. Accordingly, business decisions rely on the cost estimates and it is important that a structured estimating process be followed to facilitate transparency and continuous improvement. Cost estimates can include inflation allowance, cost of financing, and contingency costs.

As demonstrated in Figure 4-5, the overall project costs can be categorized into:

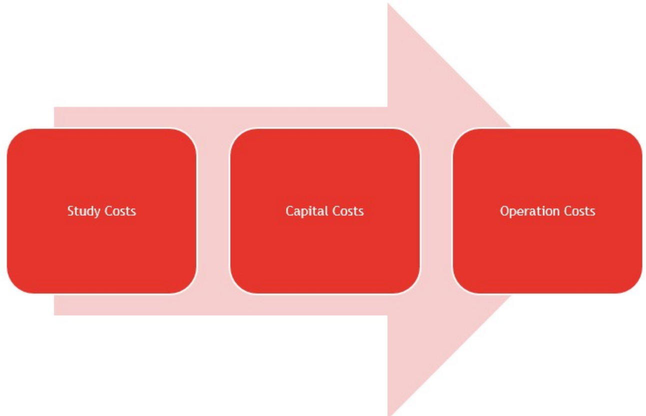


Figure 4-5 Project Costs Classification

- **Study costs** (Identification, Selection, and Definition phases costs)
- **Capital costs** (Mobilization, Construction, and commissioning costs at Execution phase)
- **Operating Costs** (Ramp-Up, and Operation Costs including fixed costs such as labour costs, fixed consumables, and fixed overheads and variable costs such as utilities, fuel, operating consumables, insurance, product transport, maintenance & spares, and chemical costs)

The standard approach to the preparation of estimates of engineering, procurement and construction management projects is as follows (Figure 4-6) [GHD. PPM Sec 05, 2011].

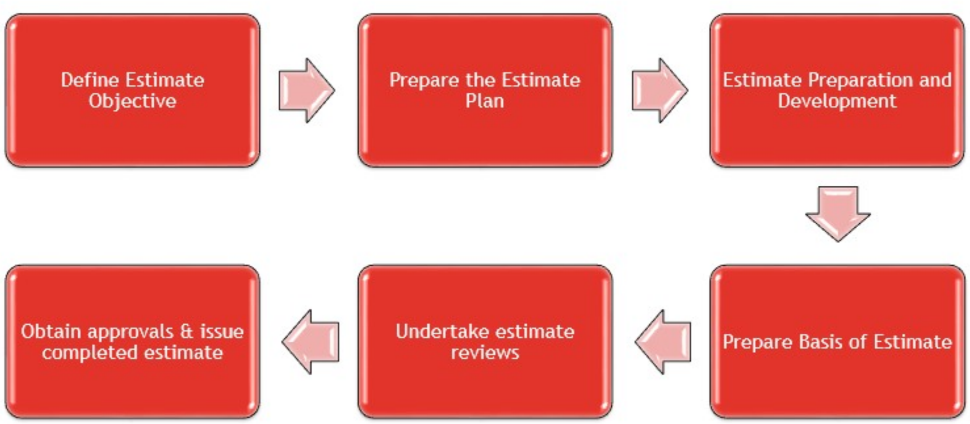


Figure 4-6 Project Costs Estimate Process

- Define Estimate Objective

    - Classification, Expected Accuracy, Project Schedule requirements
- Prepare the Estimate Plan
    - Define the scope of work
    - Prepare a schedule for preparation of the estimate
    - Hold Estimate Kick-off Meeting
    - Issue Estimate Plan & Schedule
    - Set up the estimate in the Estimating System Software according to the agreed Work Breakdown Structure (WBS)
- Estimate Preparation and Development
    - Quantify the work in accordance with the standard commodities
    - Calculate direct labour rates
    - Schedule the work on a time/logic basis
    - Determine the purchase cost of the installed material
    - Determine the purchase cost of installed equipment
    - Determine the cost of installation and construction, including the costs associated with temporary facilities
    - Establish, and allow for, the requirements for freight, duties, and taxes
    - Determine and calculate the cost for the consultant effort
    - Establish foreign currency costs and exchange rates, if applicable
    - Establish appropriate base date and escalation criteria
    - Carry out contingency/risk assessment
- Prepare Basis of Estimate (including estimate reports)
    - The Basis of Estimate document and the associated summary and detailed estimate reports will be compiled. In many respects, the Basis of Estimate document is an update of the Estimate Plan accurately reflecting what process and support has been applied in preparing the estimate.

- Undertake estimate reviews appropriate to the class of estimate being prepared.
  - Each completed estimate will be subject to a range of reviews depending upon the class of estimate. At a minimum, every estimate will be reviewed internally by engineers and then subsequently by the relevant client teams.
- Obtain approvals & issue completed estimate
  - Upon completion of all required reviews and the incorporation of any required changes, the estimate package will be submitted for approval and issued for subsequent use.

As shown in Figure 4-7 following key deliverables shall be developed under the project cost estimating process [PMBOK Guide Fifth Edition, 2013]:

Figure 4-7 Project Cost Estimating Key Deliverables

4.4.1 Cost Estimating Plan

At the commencement of study phase, the team prepares an estimating plan that is a specific guideline for preparing a capital cost estimates and consists of the following items [Vargas R, 2008]:

- Unit of measures and level of precision
- Project Scope description

- Class of estimates and expected accuracy
- Rules of performance measurements
- Estimate base date and currency
- Foreign currency exchange rate
- Reporting format
- Clear definition of study phase cost, capital cost, and operation cost
- A project WBS
- A discipline/ Commodity code structure
- The estimating software to be used
- The estimating schedule
- Funding choice
- A quantity and pricing development basis
- Guideline for capturing third party consultant estimates
- Estimating escalation for whole project
- Schedule and capital cost contingency estimating methodology
- Control thresholds process
- Qualifications and exclusions
- Client's cost estimates
- Cost controls method and procedure
- Internal and independent estimate reviews
- Guidelines for preparation of final estimate presentation package, including benchmarking and reconciliation with previous estimates
- Roles and responsibilities matrix for estimating, recording, approvals, etc.
- Funding Strategy (i.e. self-funding, funding with equity, funding with debt)

4.4.2 Study Phase Costs

The study cost estimates primarily contain the following components:

- Client`s costs (specialist consultants, travel, approvals, third party reviews, team, and other expenses)
- Contractor`s costs (sub consultants, travel, office facilities, labour charges, IT, corporate overhead & fee, and other expenses)
- Other expenses (site investigation, exploration, laboratory testing, etc.)

4.4.3 Capital Costs

The capital cost estimate is a forecast of the cost for a defined SOW and is required for every study phase. The level of accuracy of the cost estimate improves from identification phase to definition phase. These estimates provide the basis for economic analysis, budgeting & funding, cost controls, forecasting, and management decisions. It also provides input to a project cost model against which:

- Optimization of design, execution and operation can be studied,
- Changes, risks, and alternative courses of actions can be measured, and
- Alternative cash phasing can be considered

Cost estimate classifications must be used to categorize the maturity and quality of various cost estimates prepared during the life cycle of project. The requirement to achieve specific class of estimate will drive the level of scope definition required, the level of engineering development, and ultimately the scope of the study. Generally, High level estimate (ROM- rough order of magnitude) with the range of -25% to +75% is carried out at the identification phase and definitive estimates with the range of -5% to +10% is carried out at the execution phase [Oberlender G, 2000].

Key areas to be addressed when preparing a definitive estimate are [Bent J. Thumann A, 1994]:

- Level of engineering progress
- Level of construction progress

- Actual productivity levels
- Number of approved for construction drawings (AFC), discipline drawings, PFDs, P&IDs, SLDs
- Geotechnical data
- Equipment lists
- Detail up-to date material quantity take-offs for all disciplines, labour agreements for the project allowing the development of labour rates, work week cycles, work hours
- Implemented project execution strategy
- Implemented construction execution plan
- Issued request for quotation including full specifications and complete commercial terms for mechanical and electrical equipment and main bulk material supply
- Number of purchase orders placed, number of quotations received and technically and commercially evaluated, ready to place orders
- Number of tenders awarded and being evaluated
- Project progress schedule incorporating current market/project conditions, delivery dates of all long lead items, contractors' execution plan and fabrication execution plan
- Updated project histogram for accommodation requirements and construction indirect
- Updated consultant manpower schedules based on actual project execution plan, project schedule, location of design office, assignment conditions, nominated personnel including expatriates, current charge out rates for labour and expenses
- Detailed and defined temporary facilities scope including MTOs and constructability study including heavy lift carnage requirements
- Detailed report
- Estimate duration (time to prepare estimate)

The capital cost estimate is structured in accordance with the project WBS and comprises of direct costs, indirect costs, escalation, and contingencies. The direct costs include the cost of supply and installation of all permanent facilities and the indirect costs include for common distributable, implementation contractor`s service costs and the client costs.

Each area, sub area and facility of the estimate are further broken down and summarized by the main trade disciplines and sub-disciplines including earthworks, civils, concrete, structural steel, buildings & architectural, mechanical, piping, electrical, instrumentation, painting and indirect. Each estimate line item is further broken down into direct labour costs, plant equipment, bulk materials, freight, contractors` distributable, construction equipment, and subcontract costs.

All pre-commitments for goods or services made during the study phase are typically part of execution phase and these costs are classified under capital cost estimate.

Escalation is a provision in the capital cost estimate to cover the forecast increase in the cost of project inputs such as engineering labour, equipment, bulk materials, construction labour, construction equipment, and sub contracts etc. from a set point in time up to completion of project. Escalation is computed separately and independently for each major area and expresses as cash flows in nominal terms on a month-by-month or year by year basis. The above cash flows are aggregated for a total project cash flow, in nominal terms, tailored to the project location and timing. Project breakdown, cash flow of each element/ category, and application of indices are the three steps to estimate project escalation.

4.4.4 Basis of Estimate

It is important to prepare a documented basis of estimates (BOE) to clearly communicate to stakeholders the varying approximations, assumptions, and interpretations affecting the estimate, thereby avoiding misunderstandings and misuse. The BOE is issued along with the estimate for the various review and approval. The BOE structure and depth of content varies with complexity and detail of the work to be performed. It generally includes the followings [Pickett T.,2005]:

- Description of project SOW
- Class and accuracy of the estimate (the most significant variables which have impact on estimate accuracy and reliability are: level of scope definition, engineering percentage complete, project execution plan, knowledge of site conditions, estimate review process, time to operate the estimate, and the availability of professional estimators)
- Confidence level of the estimate

- Source of funds description
- Estimate base date or reference date of pricing
- Estimate summary
- Reporting currency and estimate currency table
- Estimating tools and software used
- Execution strategy such as material sourcing, sub-contracting, direct hire, off site fabrication, etc.
- List of key documents used i.e. schedule, labour agreement, organization chart
- Direct labour work cycles and productivity, Productivity is a measure of labour efficiency and is affected by local conditions under which the work is performed
- Direct labour and crew rates calculations including base rate, benefits and burdens, overtime premiums etc.
- Contractor distributable including construction plant and equipment
- Plant equipment, bulk materials quantification basis and pricing basis
- Subcontracts
- Pricing matrix broken into the awarded, budget quotes, estimated, allowance, extrapolated from data bank, and based on bids received
- Indirect cost estimate basis: Indirect works are of a temporary nature required to support the construction of the direct works (permanent facilities) including the operation, maintenance, and support services. Construction Camps, Temporary Utilities (Power, Water, Wastewater), and Paramedical Services are the example of indirect costs
- Free issue items
- Basis of design development, quantity take off and cost growth allowance. Allowances are to be added to the base estimate to cover normal engineering development and growth. Allowances are associated with specific items of work, expected to be spent on that work, and included in the base estimate along with all other identified costs
- Escalation estimate basis

- Risk assessment, contingency evaluation, and range analysis outputs
- Qualifications
- Code of accounts structure: A project Code of Accounts is required to provide a common language, which is uniformly and consistently used, to accumulate correlate, record and communicate the necessary cost-related information for the project, e.g. for estimates, budgets, forecasts, material requisitions, purchase orders, cost and commitment ledgers, invoices, timesheets, etc.
- Exclusions
- Documentation of any known constraints
- Checklist against minimum requirement for the estimate class
- Reconciliation with previous estimate
- Benchmarking against historical data

Below are the typical preparation steps for capex cost estimate at definition phase:

- Prepare estimating plan
- Prepare base capex estimate
- Develop basis of estimate
- Evaluate implementation contractor`s contingencies
- Review capex estimate
- Prepare clients cost estimate
- Evaluate project cost escalation
- Evaluate client contingencies and KPI
- Review and approve capex estimate for total scope

4.4.5 Contingency Reserves

The contingency reserves cover any potential unforeseen items of work that need to be completed , or elements of cost that are incurred, within the defined scope of work but cannot be explicitly foreseen at the time the estimate is being prepared. It contrasts to the growth allowance, which comprise of allowance for design development, quantity take off and cost growth. The growth allowances are estimated separately and added to the base cost estimate prior to contingency evaluation. At the definition phase study, the probabilistic approach known as probabilistic range analysis, entails the use of quantitative techniques such as Monte Carlo simulation [Maylor H, 2010] for translating assessed risk and uncertainty into contingency. Estimate errors, omissions, variations in labour productivity, pricing & quantity variations within defined scope and delivery delays are example of estimating uncertainties.

Contingency reserves are included in the project cost baseline, and if is assessed by the probabilistic approach, it represents the difference between the mean and base estimate.

4.4.6 Project Budget

The project budget is all funds authorized to execute the project including Contingency and Management reserves (Figure 4-8). It determines the cost baseline against which performance of project that can be monitored and controlled [Chung E, 2017].

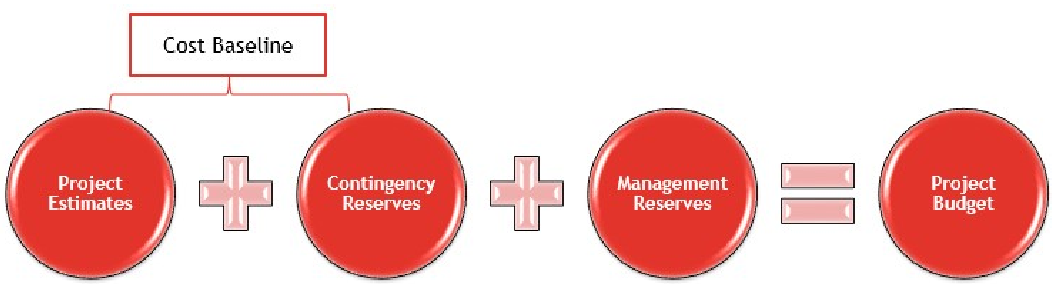


Figure 4-8 Project Budget Components

Cost Baseline = Project estimates + Contingency reserves

and,

Project Budget = Cost Baseline + Management reserves

EQUATION 4-1 Cost Baseline and Project Budget

Cost Baseline is the approved version of time-phase project budget however excludes management reserves. It is extracted from loading approved budget to the approved project schedule. Cost baseline can only be varied through the formal change control procedure and is used as a basis of comparisons actual costs. Cumulative time-phase cost baseline is also called project cash flow displayed as S-curve.

Total and periodic funding requirements are derived from the cost baseline and in this regard, it is important to determine any periodic funding limits in the project and reconcile the expenditure against it. In addition, a variance between the planned expenditure and funding limits will sometimes require rescheduling of works to level out the rate of expenditure.

4.5. Project Controls

Project control is the management and control of scope, cost, and schedule. It is essential for the project team to have current, reliable information of these critical elements to manage each phase of the project effectively and efficiently.

It is critical to project success that the project control function for both client`s team and the implementation contractor is adequately resourced and fully staffed at the early phases of the project [Wayne J.,2013].

The systems and processes for project control can provide baseline plan, status, forecast at completion, variance analysis, and management visibility through regular accurate reporting. Project controls can be divided to cost control, schedule control, and change management subsections.

Project control defines cost control [Lessard C. Lessard J.,2007], schedule control, and change management activities that are carried out during the life of the project. As shown in Figure 4-9 following key deliverables shall be developed under the project controls process.

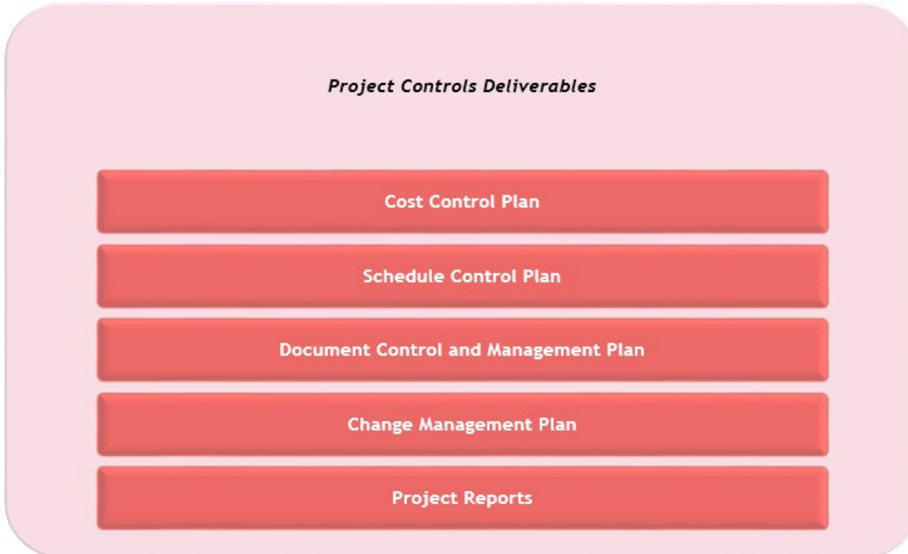


Figure 4-9 Project Controls Key Deliverables

4.5.1 Cost Control Plan

- **Cost control procedures:** cost control is the process of measuring cost performance against plan and taking corrective and preventive actions to affect desired project outcome. The well-developed and implemented cost control plan increases the probability of achieving cost KPI.
- **Baselining of original budget**, estimates are normally developed at detailed level and these are rolled up for budgeting purposes. The budget is loaded at the level of detail required for effective tracking of project performance. This normally includes job hours, labour costs, material costs, indirect costs and sub-contractor costs, to name a few, at a commodity or greater detail as needed by the project team. The approved budget will be considered as baselined budget for monitoring and controlling purposes.
- **Allocation of budget,** the budget is initially loaded into the cost control system and the status of budget will be changed to allocate when the work/ work pack is being awarded. Any changes to the current budget are normally preceded by an approved scope change requests and issuance of change order. Current budget and current forecasts are calculated as shown in Figure 4-10 [Bhp PDM, 2011].

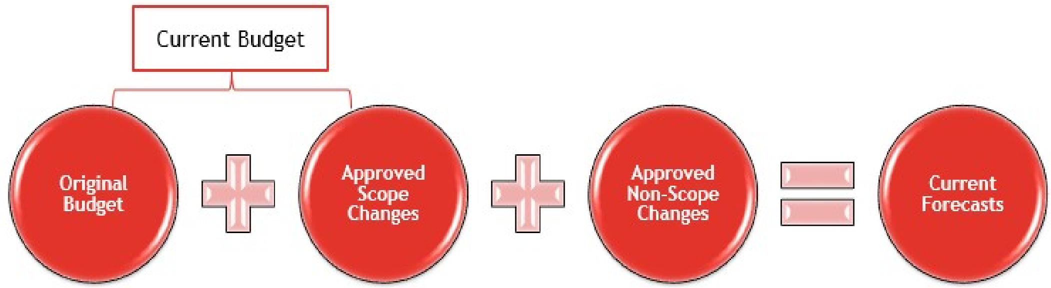
▪ 

Figure 4-10 Current Forecasts

- **Commitments and commitments curve,** a plan commitment curve is developed based on the project master schedule. Actual commitments are tracked against this plan as the project progresses.

- **Expenditure and expenditure curve,** the expenditure plan is a time phased budget and is typically displayed in the form of an S-curve. This is also referring to the performance measurement baseline and can be used to support funding requests. All invoices (even unapproved) in addition to the value of work progressed but not invoiced (accruals) are considered as expenditure (Figure 4-11) [Wayne J., 2013].

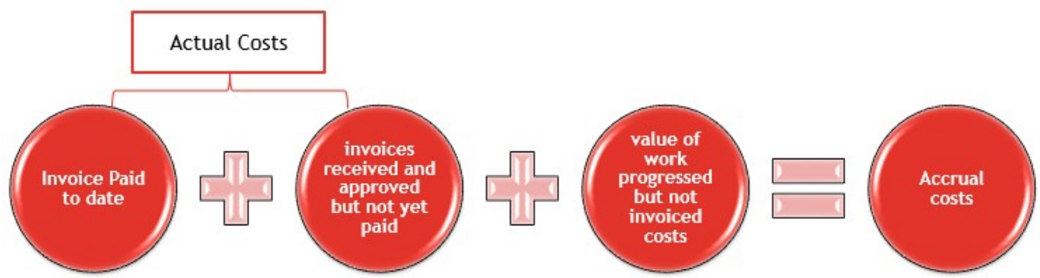


Figure 4-11 Accruals Costs

- **Contingency** is funding expressly allocated to mitigate the escalation risks only and is treated as such. It is calculated from quantitative cost risk analysis and is strictly controlled throughout the project through appropriate procedures.

- **Escalation** is maintained as a single line item and reviewed during the award of various packages.

- **Progress measurement and earned value** provides a clear understanding of the status of project in terms of cost and schedule, identifying any variance to the plan and determining if a mitigation plan is needed. The output also supports schedule and costs forecasts, estimates to complete, and estimates at completion. Schedule performance index, cost performance index, schedule variance, cost variance are the main contents of earned value report.

- **Cost forecasting** considers the actual cost incurred and the earned value. The cost performance index is one of the critical items of information in developing the forecast final cost [Lessard C. Lessard J.,2007].

CPI= Earned value/ Actual costs

- **Cost reporting requirements** shall be specified in the contract terms and conditions to eliminate any ambiguity of reporting requirements for contractors and suppliers [Sears K. Sears G, 2008].
- **Historical reports** include at least the project cost baseline report, final cost report, trend logs, any changes that impacts the project budget or forecasts, and actual hours per commodity.

4.5.2 Schedule Control Plan

- **Schedule control procedures,** a well developed and implemented schedule control plan increases the probability of achieving the schedule KPI. Schedule control is primarily concerned with monitoring and controlling of the performance of work to assure completion of project requirement as planned.
- **Baselining of project master schedule**, prior to approving the schedule, it must be verified that the schedule reflects the approved scope of work, reflects PEP, aligns with the control budget, shows the schedule contingencies on the KPI milestone, and is resource loaded.
- **Schedule curves**, Project progress curves (Early and Late curves), man-power requirements, accommodation requirements, and key commodities curves are created from baselined schedule [Frigenti E. Comninos D, 2002].
- **Revised schedule**, if the progress lags the baseline significantly, such that tracking to baselines provides meaningless information, a revised schedule is developed to reflect

the new target completion date for the project or the contract. However, the revised schedule and the new target completion date will not replace the baseline schedule or approved schedule KPI`s. Events and performance issues that cause schedule revision are managed and tracked through a schedule change log.

- **Recovery schedule** if the progress is not in track but the baseline can be recovered, the recovery schedule is developed as a part of recovery plan. This schedule clearly articulates the plan for recovering the baseline by night shifts, additional resources, etc. Once recovery plan is developed, project progress is compared with both the baseline schedule and recovery schedule.

- **Acceleration schedule**: Acceleration of the work is usually the result of an attempt by the prime contractor to apply whatever means and take whatever measures are necessary to complete the work sooner than would normally be expected for a given project under stated contract conditions. Or schedule acceleration is an attempt by the prime contractor to take extra measures to make up for delays (whatever the cause is) by utilizing whatever means are at the contractor's disposal to accomplish that objective. There are two primary types of schedule acceleration: directed acceleration and constructive acceleration A directed acceleration occurs when the client orders a contractor to speed up the work. The client is definitely in this legal position if it advanced the contractor's finish date. Constructive acceleration is present when [Hutchings J,2004]:

    - The contractor encountered an excusable delay entitling it to a time extension
    - The contractor requested an extension of duration time
    - The request was refused
    - The contractor was ordered to accelerate its work, that is, to finish the project as scheduled despite the excused delays, and
    - The contractor accelerated the work

- **Re-baseline Schedule** includes detailed analysis of remaining durations, remaining quantities, and forecasted job hours, commissioning sequences, etc. The re-baselined project master schedule can take effect only when supplementary approval request is approved as part of the response plan submittal.

- **Updated project schedule** reflects the status of the project after each reporting period.

- **Schedule contingency**, is maintained as a separate activity in the schedule, typically added to the last critical path activity. The amount of contingency increases or decreases depending on the remaining risks in the schedule.
- **Progress measurement and earned value**, while the project focuses on critical path activities, to assess project schedule performance and progress status, schedule analysis is performed to ensure any delay to the non-critical activities does not compress the schedule by creating a bow wave that could result in the need for more than planned manpower and increase in the manning density with corresponding decrease in productivity and performance.
- **Schedule forecast**, forecast dates are derived from the regular updated schedule. Schedule updates are in line with periodic cut-off dates for the schedule updates as established at the outset of the project.
- **Schedule report** is produced as part of the monthly report. It includes a written analysis of the current schedule and any recommendation regarding deviations from the baseline schedule. The report also provides an analysis of resources and productivity and forecast completion dates.

4.5.3 Document Control and Management Plan

Information developed throughout a project is considered a significant asset to the organization. This information as with all other assets must be subjected to rigorous and systematic measures of control to ensure quality, prevention against loss, traceability, and availability to all project personnel.

Project documents are documents that are required to be retained and managed to meet contractual requirements, legal, and project requirements. It contains information, created, or received, in the pursuance of any activity by any project participants. Project documents are records of communications between project participants and between the company and third-party organizations including government and non-government organizations.

Documents control plan is a document (Figure 4-12) that defines how organizations control and manage project documents, and describes document categories, document properties, document property values, document lifestyle, document review, approval and distribution matrix, document numbering, revision numbering, and document management systems [GHD. PPM Sec 09, 2011].

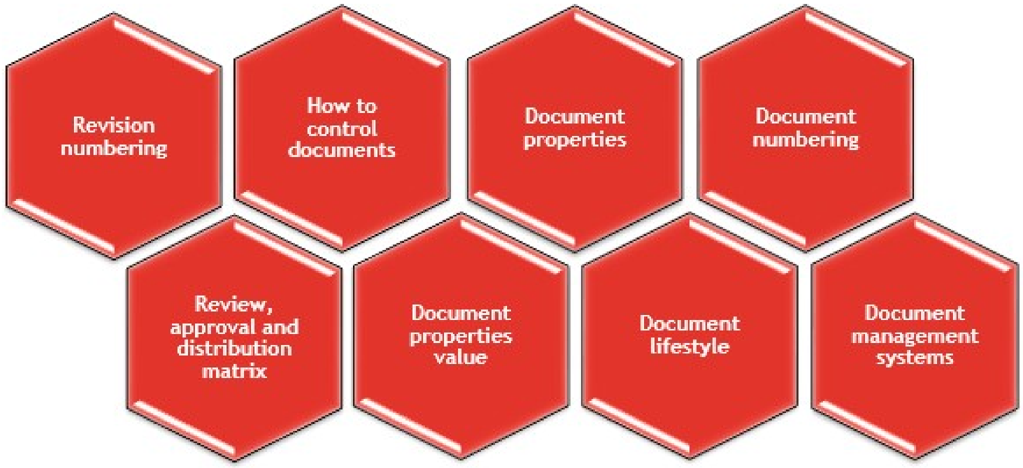


Figure 4-12 Typical Document Control Plan Contents

To control and management of the project documents, followings are important to consider:

- Project documents shall be classified using document category definitions such as technical (drawings, vendor documents, design documents, technical specifications), procedural (describing a process), general, commercial (tenders, awards, variations to contract, executed contracts), and correspondence (memos, conference notes, site instructions, technical queries, notices etc.)
- All documents shall be assigned properties that perform functions that allow the document to be uniquely identified, facilitate search and retrieval, tracking of the document throughout its lifecycle, describing the document context, managing the access to the document, and retaining audit information. Document properties include "Contract number", "Document type", "Project name", "Authors", "Document number", "Approved by", "Review date", "Review number", "Revision date", "Lifecycle status", and "Title" data
- Document property values shall be valid, consistent, and meaningful
- Electronic and hard copies shall be stored in the secure, managed repository
- A single collaboration system shall be provided that may be accessed from all Project

locations by all authorized project participants. The collaboration system will enable the sharing of information amongst all project participants and stakeholders. The sharing of information shall be included in project processes including document workflow and the transmitting of documents

- All documents shall be registered and stored in a document repository
- The document number shall be clearly visible when the document content is viewed, and document numbers shall be unique within the Project
- Documents shall be registered before being submitted for review and approval.
- The ability to perform a task on a Project Document shall be restricted to authorized personnel only. The type of access and hence the ability to perform a task shall be determined by the project participant's role
- Changes to Documents shall be recorded to provide document history and to satisfy audit requirements. The revision property shall identify each formal revision to a document. Changes to the content of a document shall be identified by a new revision. The document revision shall be aligned with the document lifecycle. Revision sequence for the update of existing documents and drawings can be "preliminary issue", "quotation only", "approved for construction", "as built".
- Documents shall be registered before being distributed. All Project Documents that are distributed, internally or externally, shall be subjected to the approval requirements. The distribution shall be recorded and auditable
- All communication, where the content of the communication is of project value shall be recorded

4.5.4 Change Management Plan

Project changes shall be identified at the early stage of project. Early identification of changes allows the project team to effectively manage the impact of these changes to the project. This requires the project to establish and implement a change management plan. Changes can occur due to number of reasons including change to the scope, change to quantities, safety in design, optimization of design, changes in business and economic climate, changes in time to market decision, etc. Not managing the changes can affect a project by increasing the cost to the project and schedule duration. The key to project success is to manage proposed changes in a controlled manner.

When the change is determined to be a scope change, in addition to evaluating cost and time impact to the project, a risk analysis is also performed, and an associated contingency value included to the cost and schedule impact. It may be required that the project go through the relevant approval process as stipulated in the project approval document. Once approved, this modifies the Client`s team current budget and forecast final cost and possibly project master baseline schedule.

In addition, non-scope change can occur when there are modifications to the packages, quantity changes, estimate errors, engineering design development, engineering, and labour productivity. Budget transfer and trends are the example of the non-scope change. A trend is any deviation from the approved schedule & budget within the existing approved scope of work. In documenting the trend, a detailed description of the change and the estimated cost and schedule impacts is provided. A trend is not a scope change and does not change the current budget. Trends modify the forecast final cost and are funded by the contingency managed by project team with appropriate client approval.

To manage the changes, the following steps as shown in Figure 4-13 must be followed [Mulcahy R, 2009].

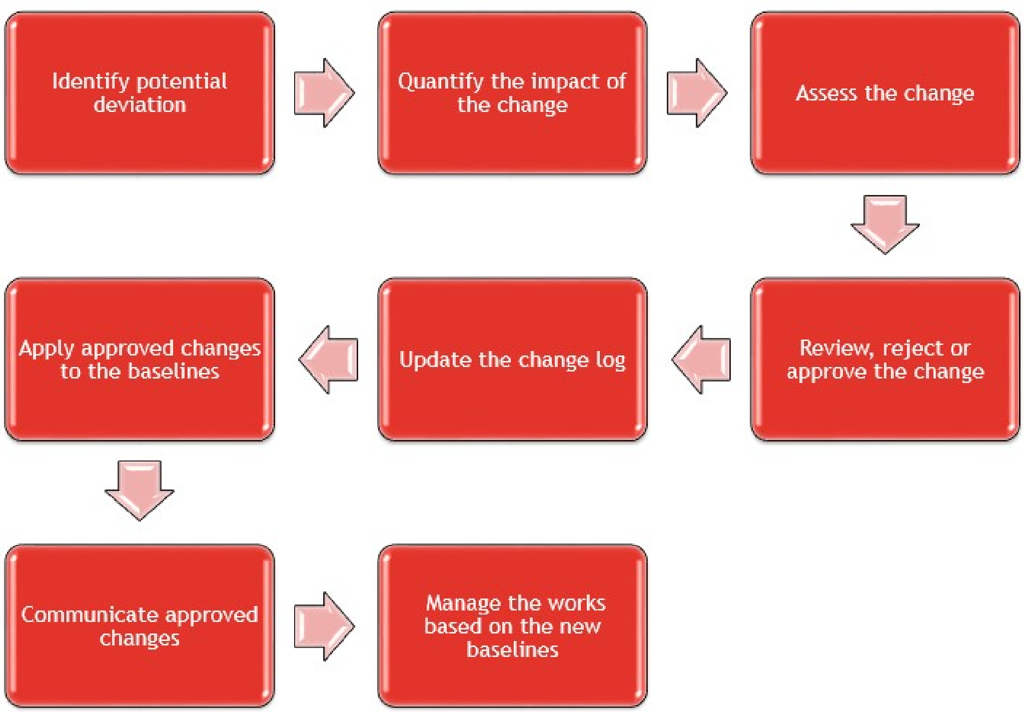


Figure 4-13 Typical Change Management Process

- Identify potential deviation and raise the notice
- Quantify the impact of the change in terms of scope, time, cost, quality, and HSEC
- Assess the change
- Review, reject or approve the change
- Update the status of changes in the change log
- Apply approved changes to the performance baselines
- Communicate approved changes to the relevant stakeholders
- Manage the works based on the new baselines

4.5.5 Project Reports

Project reports keep the project team abreast of project details and are prepared as frequently as necessary to keep the team fully informed of issues on the project. The quality of the reports is critical to ensure the management can make decisions based on critical and relevant information. Management reports will typically segment the work into logical components indicate the initial plan, performance to date and forecast to complete.

Figure 4-14 demonstrates an example of typical management report components [Hattenrath H., 2018].

Typical Management Reports include;	Monthly summary reports
	Schedule milestone report
	HSEC management report
	Schedule report
	Cost report
	Change report
	Engineering deliverables report
	Procurement status report
	Construction status report
	Key issues
	Risks and mitigation plan.

Figure 4-14 Typical Management Reports components

4.6. Quality Management

Quality in projects ensures deliverables are in full accordance with the project objectives and requirements [Wysocki R, 2004]. This implies:

- Meeting the project cost & schedule objectives
- Executing the project with no harm to people, community, and environment
- Satisfy the availability, reliability, operability, and maintainability requirement over the expected life
- Ability to deliver the design capacity
- Delivering expected value to the corporation

Quality management involves [Bennett F.L,2003]:

- Identifying the needs and expectations of the organization, its customers, and other interested parties
- Establishing quality objectives aligned with those needs

- Determining process and responsibilities necessary to attain the quality objectives
- Determining and providing resources necessary to attain the quality objectives
- Establishing and applying methods to measure the effectiveness and efficiency of each process
- Determining means of preventing nonconformities and eliminating their causes
- Implementing a process for continual improvement.

The fundamental principle of quality management is to ensure that quality is built in through the planning, design, fabrication, and construction work, rather than relying on inspection and remedial work to achieve quality requirements. As a result, a focus on quality management is introduced early in the project given that:

- The cost of Quality Assurance (QA) and Quality Control (QC) is generally much less than rectification after inspection
- There is a direct link between the quality of front-end loading, QA, cost, and
- The practice of quality management applies to all phases and activities through the development of a project and it is the responsibility of the project team to manage quality appropriate to their areas of work

It is best practice for the implementation contractor to appoint an appropriately qualified and experienced person (i.e. a quality assurance manager) to be responsible for the management and coordination of quality related activities for the project and undertake quality audits. Quality management covers the processes and activities of the project organization that determines the quality objectives, processes and responsibilities to attain these objectives and provide resources to determine the means of preventing non-conformities. Quality management process include [Tang S.L Ahmed S, 2005]

- **Quality planning-** identifying quality requirements and standards for the project and identifying how to satisfy them.
- **Quality assurance-** is the application of planned systematic activities to ensure the project meets the requirements. Quality assurance encompasses the following:
  - Quality assessment and surveillance (the continuing evaluation of the status of procedures, methods, and analysis of records to assure that quality requirements will

be met) of the quality and execution plans covering office and site

- The critical activities related to fabrication, construction, product and/or service process and the associated quality procedures and results
- Witnessing of specific quality activities and functions
- Procedural assessments to confirm the defined quality control process was or is implemented and verification records are evident
- Assessments to confirm the adequacy of the Inspection and Test Plans and that the results recorded in the verification records validate product quality, and
- The frequency of, and depth of the assessment /surveillance, shall depend on the risk and criticality category of the item and/or process.

- **Quality control-** the process of monitoring and recording outcomes of all quality activities to assess performance and compliance to the appropriate standards and identification of ways to eliminate non-conformities [Rumane A, 2011]. Quality control has the following components:
  - Production of procedures such as Inspection and Test Plans. Quality and critical execution plans, relating to the production and/or process phase as detailed in the scope of works and contract specifications
  - Performing the activities highlighted within the Inspection and Test Plans and plans at the scheduled point in the production/process cycle
  - Confirming that the tests/reviews detailed in the Inspection and Test Plans and plans verify the product/service conforms to specification
  - Field verification of product and/or service compliance
  - Corrective action procedures for non-conformance management, and
  - Distribution/retention of the resulting verification records.

In essence, QA attempts to improve and stabilize production, and associated processes, to avoid or at least minimize issues that lead to the defects in the first place and QC emphasizes testing of the products to uncover defects and then reporting these defects to management who make the decision to allow or deny the release of the product.

The following are the functional activities in quality management that need to be carried out by suitable consultants:

- Facilitate development of activity plans
- Develop and implement project specific procedures
- Develop and implement practices and forms (Figure 4-15 shows an example of Inspection & Test Plan format) [NSW.Gov,2010]
- Coordination with Workshare and another Contractor office
- Set up Quality Management System for project assessments and quality performance indicators reporting (quality performance indicators are used to measure the health of key functions and activities on the project)
- Resource management for Quality Group
- Monitor project quality
- Review contract tenders for compliance
- Attend Contractor kick-off meetings
- Assist Contractors/Suppliers with regards to quality requirements
- Conduct assessments
- Report on assessments
- Expedite responses and actions resulting from assessment findings
- Develop corrective and preventative action
- Implement root cause analysis protocols as appropriate
- Verify corrective and preventive action is suitable
- Coordinate quality activities covering offsite works
- Monthly reporting, and
- Review and approve (as applicable), Contractor deliverables such as:
    - Quality plans/manuals [Ashford J.L, 2003]
    - Inspection and test plans
    - Field Inspection Checklists

- Weld Procedures
- Welder Qualifications
- Manufacturing Data Report, and
- Personnel qualifications.

SAMPLE FORMS

Inspection and Test Plan

Customer: Contract Number: Contract/Project Name:			INSPECTION AND TEST PLAN for: *(Insert work activity)* Work area: *(Insert work area)*						*Insert Contractor Identification and/or Logo*	
Ref	Operation or stage of work		Stage/ frequency	Records	Requirement / standard/ specification	Acceptance criteria	Inspection/ test procedure	Inspection *what/who		
	Description	Characteristics						Employee	Service provider	Customer
*W = Witness Point; H = Hold Point; H(A) = Inspection/Test by Authority; U(C) = Inspection/Test by Consultant; S = Surveillance or monitoring; X = Self inspection by performer of work.										

Figure 4-15 Example of Inspection and Test Plan Format

4.6.1 Quality Management Plan

The quality management plan specifies which process, procedures and associated resources are applied by whom and when to meet the requirements of the project. The project team ensures appropriate plans are in place to achieve the quality objectives of the individual phase and the project.

As each quality management plan is project specific and aligned to the business specific drivers, scope, and execution risks, it includes the content in a fit for purpose manner. The typical structure of quality management plan is as follow (shown in Figure 4-16) [Vargas R, 2008].

FIGURE 4-16 TYPICAL STRUCTURE OF QUALITY MANAGEMENT PLAN

- Quality objectives (end users satisfaction criteria)
- The assessment strategy develops the assessment plan which lists the assessments to be performed and the stages at which they will be performed. The assessment plan will also identify the assessments to be performed in the consultant offices, Contractor offices and at the site. This strategy may be discussed with the functional managers to get their input
- Assessment schedule: The purpose of the assessment plan is to schedule the assessments over the duration of the project. It is based on the assessment strategy and coordinates with the project schedule to determine which month each assessment will take place
- Scope including applicable standards, specifications, regulations & laws, codes, statutes, and certifications of third parties.
    - QA/QC requirements for engineering activities include but not limited to performance requirements, availability, reliability, operability, and maintainability, sparing of equipment, project life expectancy, expandability, standardization, design specifications, consultant appraisals and evaluation, engineering software and so on.
    - QA/QC requirements for procurement activities including but not limited to inspections, hold points, factory acceptance testing, preservation and storage, identification and traceability, witness testing of the various contracts, and purchase orders.

- QA/QC requirements for construction activities as defined in the contract and quality management plan
- QA/QC requirements for commissioning activities including mapping engineering, procurement, and construction packages, procedures, checklists, performance testing, commissioning documentation, handover certificates, running trials, agreed punch lists, as built drawings, operating and maintenance procedures.

▪ Communication (pathways and contact points)

▪ Resources (team, training, and external resources)

▪ Controls (required procedures, reviews, and audits, process for handling non-conformances and corrective actions, control of documents and records)

4.6.2 Process Improvement Plan

This document is a key aspect of the project management plan. Project managers should improve current process in use on the project. This helps save time & money by increasing efficiency and preventing problems. The process improvement plan details steps for analysing project management and product development processes to identify tasks that enhance their value. The process improvement plan further includes targets for improving performance, process metrics, configurations, and process boundaries [PMBOK Guide Fifth Edition, 2013].

4.6.3 Quality Checklist

A quality checklist is a list of items to be inspected, steps to be performed in the quality control process. Quality checklists should incorporate the acceptance criteria included in the project scope baseline [Ashford J.L, 2003].

4.6.4 Quality Metrics

Metrics are essential to identify what measurements are acceptable in the specific area of the project. It describes a project attribute and how the quality control process will measure it. Quality metrics are used in the quality assurance and quality controls process. Failure rate, availability, reliability, defect frequency, and test coverage are the example of quality metrics. Additionally, tolerances can be defined as allowable variations to the metrics [PMBOK Guide Fifth Edition, 2013].

4.6.5 Quality Reports

As shown in Figure 4-17, the quality team generate several following reports [Rumane A, 2011].

Figure 4-17 Typical Quality Reports

- Assessment Reports
- Corrective Actions
- Preventative Actions
- Observations
- Non-conformance Reports
- Procurement and Contract Quality Surveillance Reports
- Construction Contracts QA/QC Management Responsibility/Activities Report

- Inspection Reports that are generated in the field covering QA monitoring related to construction contracts offsite works [Kerridge A. Vervalin C,1986]
- Summary Reports that cover several documents and logs
- Non-conformance Report logs as applicable
- Monthly Report including:
  - Assessments conducted
  - Assessment status
  - Corrective action log
  - Preventive action log
  - Quality performance indicators monthly summary, and
  - Quality control summary including non-conformance log.

Also, as an example, at project close out phase, QA/QC report shall include:

- A summary covering an overview of the Scope of Work including brief detail related to QA/QC issues, non-conformances raised, the number of internal/external audits conducted, rework and concessions and details of Construction/Manufacture Program slippages complete with incumbent remedial actions taken to achieve program
- A copy of the Audit log
- A copy of the corrective action log
- A copy of the Non-conformance log
- A copy of the Technical Query log
- Deliverable Documents List, and
- Lessons learned

4.7. Value Improvements

Value Improvement aims to maximise the value of a project opportunity by identifying the value creation areas within the opportunity and applying selected techniques to optimising the project scope and/or approach.

The broadly accepted process to optimise project value is to apply selected value improvement practices (VIP). During the Pre-feasibility and Feasibility phases of a project, a VIP Plan should be developed and progressively implemented.

Development of the VIP Plan will involve reviewing the VIPs and determining which VIPs shall be applied to the project. Some VIPs are considered essential to the successful delivery of projects. These VIPs are mandatory and include [Smith N, 2002]:

- Project/decision framing
- Lessons learnt and best practice
- Value engineering
- Constructability reviews, and
- Maintenance development

Value improvement practices (with some exceptions) are a collection of analytical techniques designed to examine key components or aspects of a project scope of work in order to determine where changes can be made to optimise the project value. The techniques can be applied to any project, but the greatest potential is in the study phases of the project.

Value improvement utilises a range of straightforward techniques to apply structured analytical and creative thinking to an existing or new requirement of a project. Value improvement can be applied to all projects since it is a powerful means of measuring what can be eliminated or reduced and is a potent and stringent measure of quality control. It provides structured examination of the project concept and all elements of such a project. It asks the question “why” in a structured way and is also “is there another way or better way of achieving the project objectives.” From the analytical phase, it works through a creative phase followed by an evaluation and investigatory phase through to a final recommendation and implementation plan.

It provides tangible and practical results, which can potentially lead to substantial saving in capital and/or operational costs. These techniques should not be regarded as cost estimate reducing exercises to justify a project being approved to the point where project value is lost and whole of life aspects are seriously compromised.

Value improvement should be viewed as much about validating that the scope of work is “Fit-for purpose" (which potentially can lead to inclusion of additional scope) as it is about reducing the estimated cost.

Value improvement process functional workflow is as follow (Figure 4-18) [Smith N, 2002].

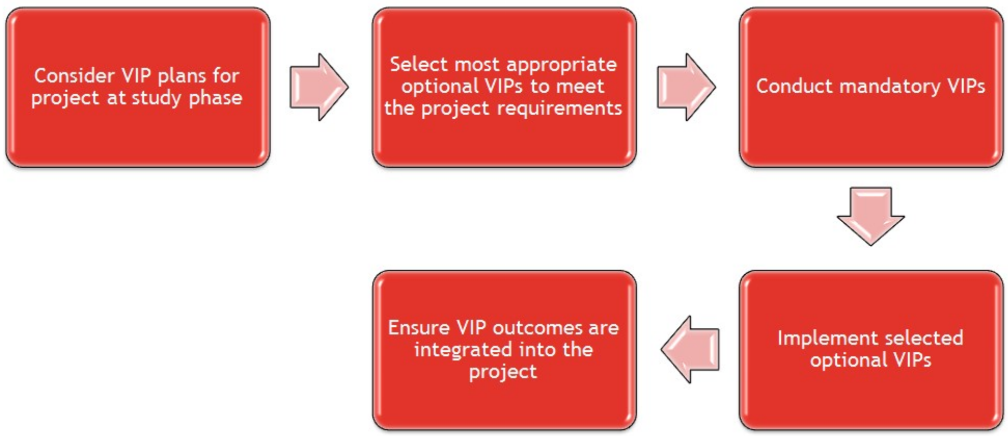


FIGURE 4-18 **Value Improvement Process Workflow**

- Consider VIP plans for project at study phase
- Select most appropriate optional VIPs to meet the project requirements
- Conduct mandatory VIPs
- Implement selected optional VIPs
- Ensure VIP outcomes are integrated into the project

Selection of the most appropriate VIPs is the key to optimising the accrued value. It is not expected that all VIP will be applied to each project. Rather it is expected that a select sub-set of the applicable VIPs will be applied.

Below is the list of value improvement practices as shown in Figure 4-19 [Lozon J. Jerageas G, 2008].

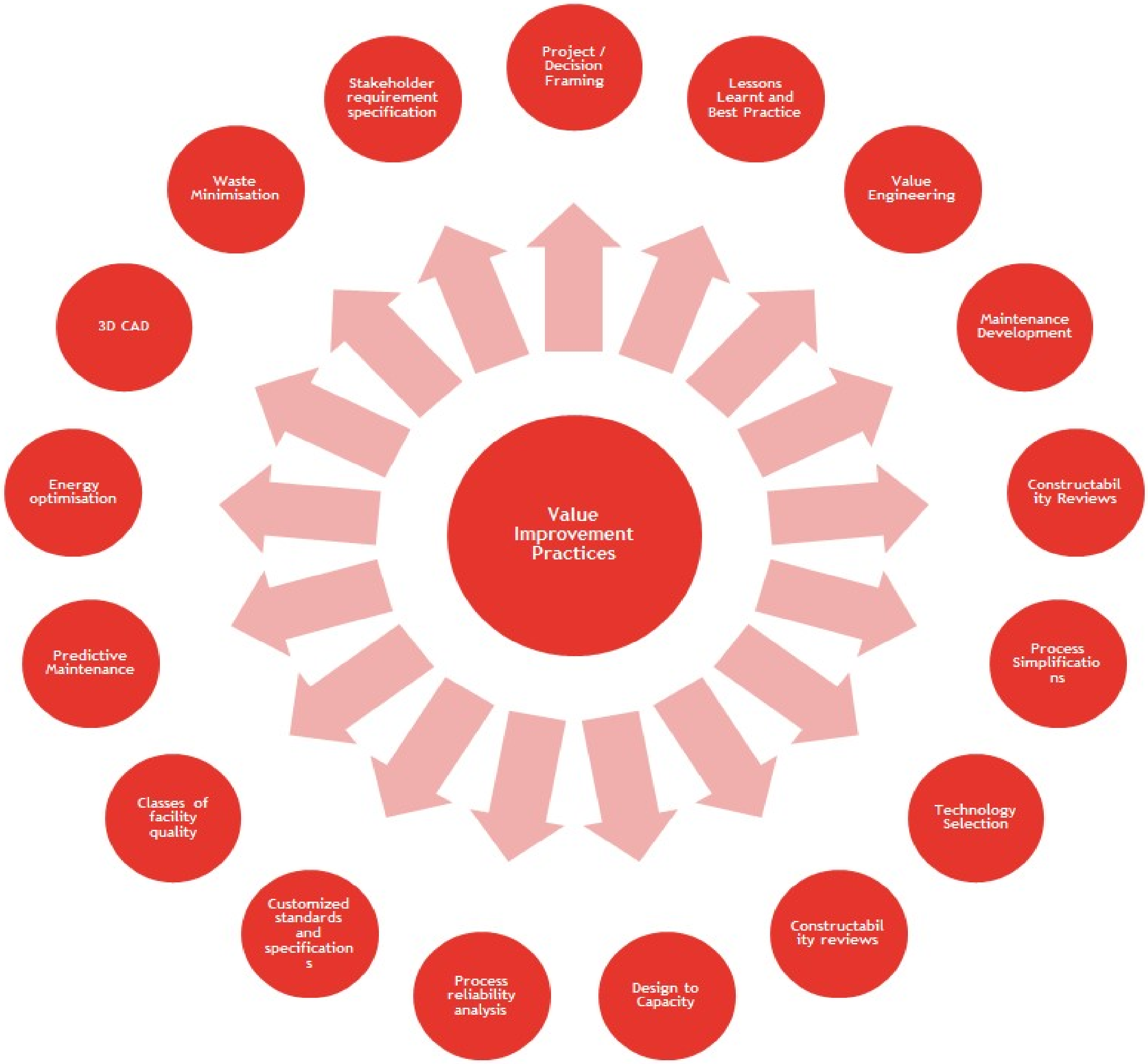


FIGURE 4-19 **Value Improvement Practices list**

- **Project/Decision Framing:** to identify the objectives of the project, the associated scope, and the project boundaries.
- **Lessons Learnt and Best Practice**: to capture both positive and negative learning's from previous projects for inclusion in Project Execution Plan and Risk Management Plans. The review should not be limited to projects that have been completed within the organization.
- **Value Engineering** is to meet the business objective(s) of the project at the optimal cost by eliminating non-value adding investment and ensuring tight alignment

between the project scope and objectives [Lipton S, 2012].

- **Maintenance Development**: An ongoing process of maintenance development activities during the prefeasibility study and feasibility study phases to ensure successful transition of design and construction activities into commissioning and speedy optimization of plant operations and maintenance.
- **Constructability Reviews** is to systematically evaluate the design to improve construction efficiency and safety during construction and to ensure that all construction issues and methodologies are captured in the project estimate.
- **Process Simplifications** is to focus on eliminating unnecessary (or combining) operating process steps or equipment to improve cost, schedule, and operational flexibility. Process simplification may be applied to new or existing facilities to improve capital, operations and maintenance cost, product quality, production capability and flexibility, waste reduction and inventory reduction.
- **Technology Selection** is to ensure that all alternative technologies for accomplishing tasks are rationally considered in a structured manner. This strategic approach to select the most appropriate technology also needs to include a key focus on balancing risk and reward.
- **Design to Capacity** is to systematically review the maximum operating capability of each major item of equipment within the context of the operation of the entire facility. This sets the lowest practical design factors and minimises excessive redundancy with due consideration given to the impact of the project on existing infrastructure and scope and likelihood of future expansion.
- **Process reliability analysis** is to enable identification of bottlenecks in the process and to understand the assets sparing philosophy that meets operability goals and minimises the capital costs.
- **Customized standards and specifications**: are to ensure that the facility costs are not increased by applying codes and standards that exceed the actual needs of the plant. This may include company standards and specifications that are onerous and outdated.
- **Classes of facility quality**: Is to establish what quality of plant is needed to meet project objectives in terms of expandability, reliability, product quality, process flexibility, maintainability, life of plant & equipment and redundancy.

- **Predictive Maintenance** is to improve plant maintainability to reduce unnecessary maintenance requirements and to improve plant operability.

- **Energy optimisation** is to examine the types of energy used, energy consumption and optimizing the trade-off between capital and energy costs.

- **3D CAD** is to reduce the frequency of dimensional errors and spatial clashes to minimize construction errors and rework as well as to aid visualization in operation and maintenance training.

- **Waste Minimisation** is a stream by stream analysis of the process to reduce or eliminate no useful streams and by products. The emphasis should be on source reduction or waste product re-use.

- **Stakeholder requirement specification**: Provides a clear and unambiguous statement of the project requirements in measurable terms. This specification is designed to align business needs with project deliverables.

The key steps involved in implementing the value engineering workshop include [Lipton S, 2012]:

- Clearly define the process and objectives of the project and document the key project deliverables

- Prior to undertaking the workshop, there are several pre-requisite documents that are required to be available to the facilitator and VE workshop participants. These include, but are not limited to the stakeholder requirement specification, scope of work, estimate (Capex and Opex), project execution plan, implementation strategy, project schedule, financial model and drawings (layout, general arrangement, process flowsheets, P and IDs as a minimum)

- Break the project down into smaller key elements, document the estimated cost of each element and its contribution to key project deliverables

- Critically question the value of each component:

    - Is it needed to meet project objectives? What is the consequence without it?

    - Can it be done differently?

- Brainstorm.

Supporting Documentation

- Go/no go on further study detailing
- Idea title and owner
- Estimated savings or increased costs.

During the VE process

- Aim to spend time in proportion to estimated allocation i.e. What are the "big ticket" items?
- Focus on the scope of work and not the estimate
- Deals in facts, not emotions
- All ideas/opinions are considered equally
- All representatives are accountable for the outcomes
- Be positive – not negative or defensive
- Think radically – outside the square
- The process should be completed in one meeting, and
- The Client Team participant is critical to a successful VE outcome.

4.7.1 Value Improvement Plan

A value improvement plan is prepared to specifically identify and plan the value improvement activities that will be undertaken during the selection, definition, and execution phases of the project. A typical value improvement plan includes coverage of topics as summarized as shown in Figure 4-20 [Lozon J. Jerageas G, 2008].

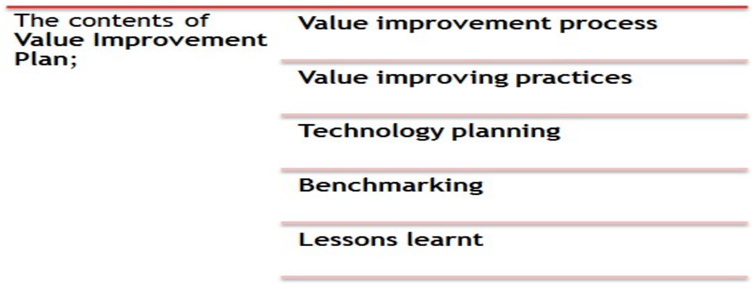


FIGURE 4-20 Value Improvement Plan

- **Value improvement process**: an outline of the process to be followed to obtain maximum value improvement over the life of the project.
- **Value improving practices**: includes
  - A review of the VIPs to determine which ones are applicable to the project (note that some VIPs are mandatory).
  - The proposed timing for each of the VIPs: This is driven by the development of the key input deliverables required to perform the VIP and the appropriate timing within the project phases to support timely decisions and to prevent unnecessary re-work.
  - A designated Client's team VIP champion who has the responsibility for driving the use of VIPs.
  - The provision to repeat a VIP as more information becomes available during the project development phase.
  - A check step to review the VIP list, as some becomes relevant or irrelevant, throughout the project life.

- **Technology planning:** an outline of the proposed technology planning to be undertaken over the life of the project.
- **Benchmarking:** An outline of the proposed benchmarking to be undertaken over the life of the project.
- **Lessons learnt:** an outline of the lessons learnt process to be undertaken.

4.8. Organization and Staffing

The project team is widely considered the foundation of project success. Projects would not be able to achieve their objectives without the right people and teams in place during the project life cycle. Major factors in ensuring a project's success is the assurance that firstly, project teams possess the right skills and experience and secondly, that they work as a single high performance team with good team alignment [Mathis R. Jackson L, 2008].

4.8.1 Organizational Structure

It is important to develop the project organisation structure using a top down approach. This commences by defining how the project is positioned within the business. It maps out the reporting structure of the project and includes joint venture arrangements, steering committees and relationships with existing operations and business units.

Once the business level interfaces are established the project level organisation structure is defined in greater detail which includes the Client's team, implementation contractor and other contract organisations where relevant. The roles and responsibilities of the Client's team and implementation contractor are clearly identified and communicated to the project team.

The larger the project scale, the greater team integration becomes critical to success. Therefore, the business and project leads must make all attempts to ensure integration of the team. Some of the more common reasons for using Third-Party suppliers are the following [Richardson G.L. Jackson B.M., 2019]:

- Internal resources are stretched to capacity and an external vendor provides temporary relief that constraint
- External vendors have niche skills that are not available in house
- External vendors can do it cheaper because this can be a speciality for them
- An external vendor may have more flexibility to meet the schedule required
- The buyer organization does not want to hire staff for that class of activity

The organization structure for the project team and the associated responsibilities vary depending on the phase, project size, execution strategy and contracting plan for the project. The project is overseen by a steering committee to ensure successful delivery of the project and provide strategic guidance to the project leader. The steering committee is established in the selection phase of the project and continues until project completion.

As an example, a typical organization chart in construction industries includes the engineering, construction, procurement, contracting, Project Management, Environment, health and Safety, Planning & Scheduling, Project Controls, Human Resource, Finance, Maintenance, Operations, and Business departments.

Figure 4-21 is an example of the organization chart for a project management team [Sepehri P. Mousavi S, 2011].

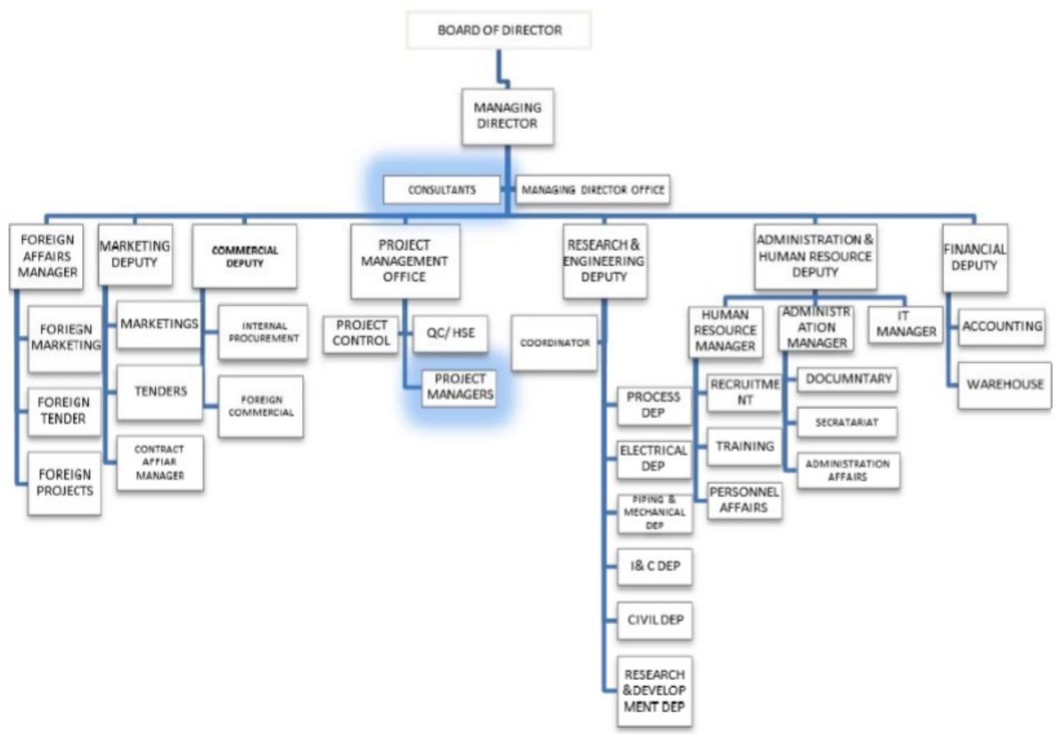


Figure 4-21 Example of organization chart of Project Management team

Ultimately, the organizational structure reflects the key factors affecting the project such as project scope and the local culture. Once the organization chart is developed, the other key activities commence including development of the mobilization plan, roles and responsibilities and competencies.

Figure 4-22 Typical content of HR management plan

Organization structure can be Functional, Project, Matrix, and Composite type. It is also dynamic and changes as the project progresses from the study phase to the execution and operation. It is important that it is reflected diagrammatically and distributed on a regular basis.

4.8.2 Human Resource Management Plan

The HR management plan is a core requirement during the project life cycle. It is essential that it is formulated in conjunction with the allocated implementation contractor to identify major risks to the people component of the project i.e. difficulty in attracting resources to project location, industrial relations etc.

A typical content of a project HR management plan is shown in Figure 4-22 [Vargas R, 2008]:

- **Resource planning**, details how the organization is positioned to support the delivery of project resources, outlines the workforce requirements for project and provides a basis from which performance in recruiting can be measured and controlled. To plan resourcing, it is critical to assess the current labour market where the project is located, to understand the business ability to source the right people under the right conditions, and to consider availability of internal shared resources.
- **Organizational chart** shall suit to the project phase, project size, scope, execution strategy, organization culture and project contracting plan.
- **Roles and responsibilities** define the roles required and core responsibilities including the interface with key stakeholders. In finalizing the project organizational structure, roles and responsibilities are clearly defined to ensure that the skills, competencies, experience, boundaries, and authorities are articulated for each of the roles. This assists in minimizing overlaps, gaps, and misunderstandings between the people on the project and sets a platform for a successful team.
- **Organizational levels**
- **Location and site conditions**, outlines site conditions and location considerations. Prior to initiating recruitment activities, site conditions and hours of work are clarified for each phase of project. This assists in the formulation of the recruitment strategy in terms of resourcing from different locations and travel implications. Accommodations in the remote area, transport solutions, allowances, and rosters prior to commencing recruitment are key factors that need to be considered in plan.
- **Recruitment strategy**, a comprehensive guide to the recruitment approach defining the process of engaging project team. This includes the mix of employment type, target recruitment advertising locations, remuneration approach (salaries and contract rates), resourcing strategy, mobilization requirements, recruitment workflows (such as interviews, reference checking, medicals and psychological assessments), retention strategies (work environment, project completion bonuses and good leadership skills are examples of contributing factors to ongoing retention) and demobilization & release program.
- **On-boarding**, considerations in the people on-boarding process. Inductions, IT support,

work medicals, etc. are all essential in ensuring the smooth transition of personnel onto the project. An efficient on boarding process can greatly reduce the time taken to bring people in the project.

- **Performance management** outlines the company`s performance enhancement process. The objectives of conducting performance enhancement includes clarification of roles and responsibilities, constructive feedback to team members, discover of unknown or unresolved issues, establishing individual development programs and defining specific goals & KPIs for future time frames.
- **Development and training**, outlines considerations for training and development of project personnel. Identification of role competencies and gap analysis is the foundation of this work. Training available in the organization and externally should be identified with an appropriate timeline that integrates with the performance management process.

A good framework for development and training is required that consists of:

- Capability development program including a competency assessment process, individual development plan, and project management competency framework
- Career pathway model with consideration of gradual progression from one project type to the next over time.
- Development & training strategies. Key areas for development of project people include: health and safety leadership, leadership skills, communication skills, dispute resolution, team development/ coaching, project management, organizational skills, equal opportunity, harassment prevention, fair treatment process, and cultural awareness. The purpose of these training initiatives is to ensure that project management and supervisory personnel have the appropriate leadership skills to support the project objectives.

- **Organizational development**, reference to the requirement for the project teams to undergo team integration and development. It provides further background and suggestions on how to integrate project teams efficiently and successfully. Specific emphasis is required on ensuring:
  - The team is clearly aligned with the project objectives
  - The team understands the roles, responsibilities, and accountabilities of all team members

- A rewards and recognition programs are embedded
- A communications program is in place to keep the team informed of project events
- Opportunities for career development are present

- **Turnover**, importance, and application of measuring project turnover. It is monitored and used as a control point for the project. High turnover can be a symptom of many factors including poor working environment, lower than market remuneration, uncertainty in prospects or an overall lack of a sense of belonging to the organization.
- **Employee/ industrial relations strategy,** key considerations in the formulation of the employee and industrial relations plan. The strategy describes the criteria for establishing the policies and practices applicable to a specific project to ensure that sound employee/ labour relations are maintained during the execution phase of the project.
- **Communication and interfaces**, reference to the requirement for a communication strategy. Communication is a fundamental aspect of project planning, ensuring all stakeholders are kept fully informed of project progress including highlighting relevant issues and successes. It is an established practice to ensure the project team is kept abreast of what`s happening in the project and are involved in positively contributing and celebrating the achievements of the project. Method of communication, open & frequent communication, individual & team accomplishment, stakeholder`s involvement are the key consideration in communication planning.
- **Risk assessment**, identification of risks associated with the resourcing and management of project team. Labour shortage, resource availability, industrial relations issues, issues related to travel to the site are examples of labour risks.

There is a requirement for key project resources to meet the minimum competency and experiences standards. It is the supervisor’s responsibility to ensure that resource capability meets core skills and experiences criteria. In the resource constraint environment, where people may be employed who don’t meet the set criteria, suitable strategies need to be implemented to mitigate the associated risk.

4.9. Stakeholder Management

Stakeholders are persons or organizations that are impacted by, would benefit from, or have influence on the selected project. Their interests and involvement vary widely. Their stake may not be always financial interests or have a positive outcome. The key objectives of stakeholder management are to [Smith N, 2002]:

- Understand their needs and expectations
- Gain a better understanding of issues from stakeholders` point of view
- Respond to the above appropriately and promptly so that they do not become a roadblock at a later stage.
- Align the expectations, aims and objectives of the company within the project, to assist in facilitating a smooth transition to the next phase work

Stakeholder management begins at the commencement of the identification phase and is a continuous process through all phases of the project. Activities within stakeholder management are conducted at regular and frequent intervals with key issues revisited as various milestones are achieved. These activities are recorded in the stakeholder management plan or register.

Effective stakeholder management increases the probability that the development of the project through each of its phases proceeds smoothly, by facilitating the completion of signoffs, approvals, authorizations and permits without delay or re-work. It also serves to counter negative perceptions and avoid escalation of third-party objections that could potentially delay the project. There is often a need to incorporate and embrace the community, government, and non-government organizations in any negotiations, to maximize buy-in to the project. Ignoring such issues in the early stages of the project development can lead to intractable problems later.

Stakeholders can be either internal (employee, joint venture partners, project team, and shareholders) and external (local communities, government, suppliers and contractors, customers etc.). It is critical to identify all internal and external stakeholders and assesses their needs, requirements, concerns and manage their expectations to contribute to the successful outcome of the project. Relationships with external stakeholders are managed by appropriately qualified and experienced personnel [Sutterfield et al., 2006].

4.9.1 Stakeholder Management Plan

The key document to be developed in this process is a stakeholder management plan consisting of the followings as shown in Figure 4-23 [Susniene, D & Sargunas, G,2009].

FIGURE 4-23 **Typical content of Stakeholders Management plan**

- The stakeholder register contains list of stakeholders, their interests, influence, involvement, concerns, requirements, and potential impact on the project.
- Identifying all the stakeholders for the project is an important step and following this, the level of stakeholder support/interest and their potential influence on the project shall be assessed. As the stakeholder register is developed, the stakeholder analysis is undertaken to categorise stakeholders based on a combination of their level of interests and their influence on its outcomes based on the power of their organization and/or the level of their authority. Both the impact of the project on the stakeholders and the potential impact of the stakeholder on the project are evaluated using a support and influence chart. The chart assists in identifying who are the most important stakeholders, their level of influence on the project and hence the level of effort that needs to be expended in communicating with them.
- A strategy is then developed for each stakeholder, including the frequency and level of contact to maximise positive outcomes with that stakeholders. This is documented in a communication plan, which is then used to facilitate the most efficient application of resources to each stakeholder, according to the ranking of each stakeholder`s needs.

The list of stakeholders is likely to change as the project matures as new stakeholders become involved and the interests and influences of established stakeholders change

- Legal and regularity approvals plan, includes register covering permitting and approval requirements, outline of all approval processes, and documented plan to manage these requirements
- Key contracts list (e.g. power, water) contains a summary of all key contracts and agreements. Contracts to consider for inclusion in the contracts list include those contract for which long-term commitments must be formed, contracts for services of significant scope during study phase, and pre-commitments required prior to commencing the execution phase.
- Joint venture interface plan if applicable, includes identification of all partners, the right, roles, and responsibilities of each party, and a plan to manage the interface and communications between the project team and the joint venture partners.

The objectives of the stakeholder management plan is to document how the expectations of the identified stakeholders are managed and aligning them towards supporting status. It includes a description of how to obtain feedback from stakeholders, address the issues as they occur, analyses stakeholder concerns and prepare mitigation plans.

Analysis of past project performance demonstrates the following success factors in effectively managing stakeholders [Chinyio E & Olomolaiye P, 2010]:

- Leadership at project and business level
- Major projects require significant commitments and contribution from most functions in the corporation
- Confidence and trust in business by internal and external stakeholders
- Continuity of involvement from those who undertake stakeholder's management responsibilities
- Involving the right stakeholders at the right time enhances successful project outcomes
- Strong local knowledge and presence

4.10. Communication Management

Over 90 percent of project management time is spent engaging in various forms and means of communication. Project managers should create communication management plans, requesting stakeholders to provide information on what they need communicated to them, issue project status report, and frequently revisits communications at team meeting to limit the communication problems [Mulcahy R, 2009].

To plan communication, the following are required:

- Communication technology
- Organization cultures and standards
- Communication methods including interactive, push and pull communications
- Communication models includes at least three parts: Sender, Message, and Receiver
- Organization`s procedures
- Stakeholder register
- Stakeholder management strategy
- Lessons learned

4.10.1 Communication Management Plan

The communication plan, describes what, when, where, how and with whom any of stakeholder communication occur, description of the key messages to be conveyed, how changes in stakeholders` interests are documented, how communication is implemented, how any issues are addressed [Alam M, 2016].

The communication management plan is designed to provide a basis for timely interaction and information sharing with stakeholders. The objective of the communication plan is to get the right information to and from the right project stakeholders at the right time. Each stakeholder has a different requirement for information, given that they participate in the project in the different ways. Communication management plan contains the followings as shown in Figure 4-24 [Vargas R, 2008].

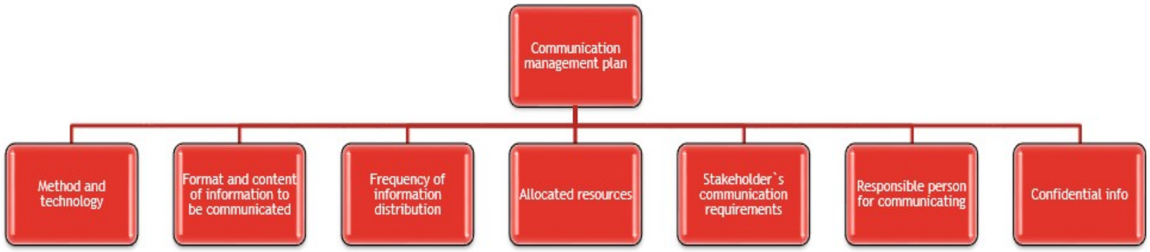


FIGURE 4-24 Typical content of Communication Management plan

4.10.2 Project Information Systems Plan

Appropriate project information systems provide enabling support for all project functions. Each project will require a combination of 'standard' Information Systems/Information Technology infrastructure, the deployment of a standard suite of applications plus specific systems required to support the needs of the project. The deployed systems then need to be supported through the project phases and ultimately de-commissioned once the project is complete and closed [Amrollahi A & Ghapanchi A, 2014].

A key enabler to the acceptance of the Master Program Office (MPO) was the usability of the project tools that made up the Project Management Information System (PMIS). The PMIS was used to track and maintain control over the company's portfolio of Year 2000 projects. A Lotus Notes database, dashboard-type control panel, along with electronic mail, served as the "user front end" to allow navigation through the various project management data collection and control applications as follows:

Figure 4-25 demonstrates a sample of what the Project Management Information System (PMIS) contained:

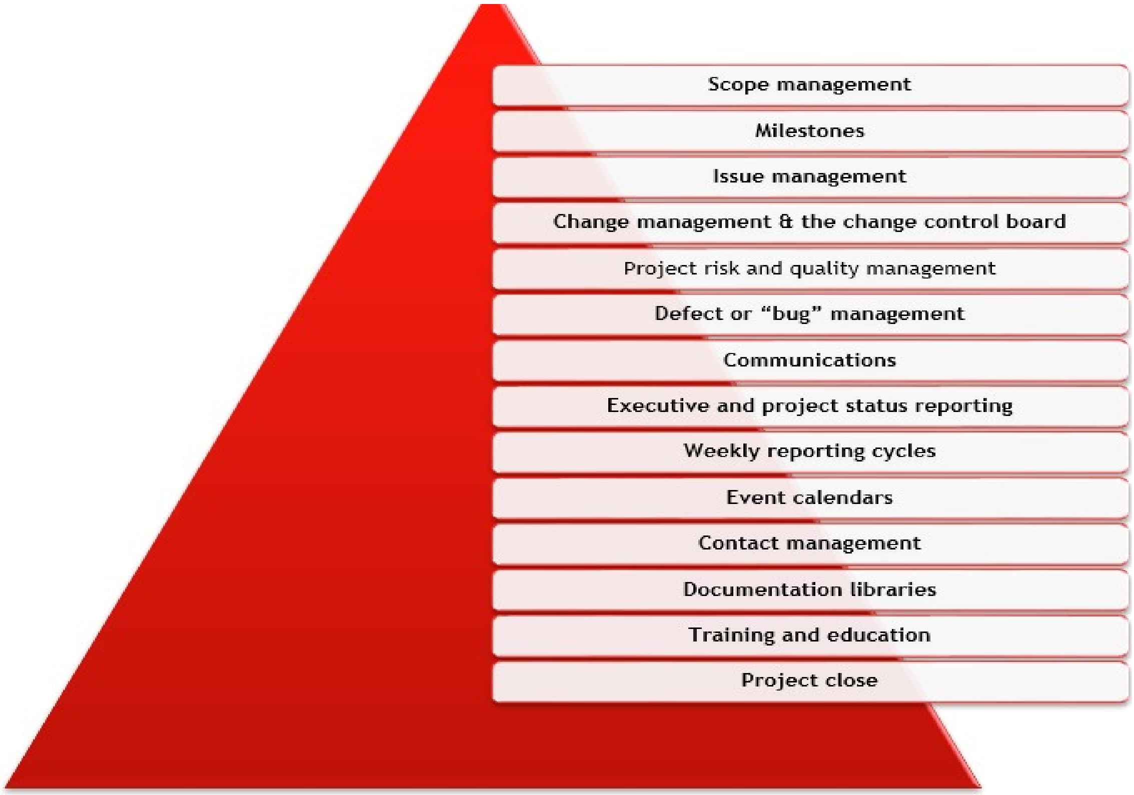


Figure 4-25 Typical PMIS contents

- Scope management (e.g., the project charter)
- Milestones (planning integration and scheduling management with milestones)
- Change management and the change control board
- Project risk and quality management (i.e., project audit and reviews)
- Issue management
- Defect or "bug" management
- Communications
- Executive and project status reporting
- Weekly reporting cycles
- Event calendars
- Contact management
- Documentation libraries
- Training and education
- Project close

4.11. Risk Management

Risk is defined as the potential impact of uncertainty on objectives. Risk management includes the process of conducting risk planning, identification, assessment, prioritization, response plan, monitoring and control on the project. The objective of project risk management is to increase the probability of opportunities and reduce the probability and impact of negative events.

Risk management is the strategic process that is undertaken in all phases of a major capital project from initial conception through to closure of the project phase. There will be changes in risk issues and their profile as the project matures and therefore risk management is a continuous activity during each phase of development. Potential operations and closure risks are also identified throughout the project phases to ensure the design is developed to enable these risks to be eliminated or effectively managed.

The management of risks on major projects is carried out in compliance with the business risk management requirements and procedures. As a project phase is executed and completed, the risks particular to that phase may no longer be applicable provided they have been effectively closed out. The remaining risks are carried forward, while new risks are identified and become more clearly defined and more accurately quantified as the following phase is developed. Hence risk registers become a live document that are continuously revisited, reviewed and updated as the project matures [Horluck J, 2009].

Risk management processes are an integral part of overall management process for a project development. Therefore, it is critical that an effective risk management process and effort is used to identify and proactively manage risk issues well in advance of them manifesting themselves as critical project issues.

Clarity of the ownership for different risks across a project development process is required. The owner`s team is accountable for the implementation of risk management, ensuring risk management process in line with the organizational assets, and identifying and managing all project risks.

The risk manager does not own the project risk as the main responsibilities include [PMI Practice Standard for Risk Management, 2009]:

- Ensuring that there is compliance with the organisational procedures
- Ensuring that sufficient and capable resources are in place for ongoing facilitation of

risk assessment

- Ensuring that all the appropriate risk management forums are in place, from facilitation workshops to ongoing monitoring meetings
- Ensuring that assigning of responsibilities for implementation of mitigations is a clear and transparent process regularly enforced at monitoring meetings
- Planning, coordinating, and monitoring the risk management process and resources
- Ensuring that the risk assessment content is communicated to the workforce in appropriate forums and formats
- Preparing an overall risk register that combines all the separate registers and plans emanating from the various workshops
- Coordinating self-assessments of the critical controls and monitoring implementation of improvement tasks
- Ensuring that risks have been ranked in consistent manner

Elements of the risk management framework are [Tinnirello P, 2000]:

- Risk assessment scope and resources
- Risk identification, analysis, and evaluation
- Risk monitoring evaluation and control

A critical source of risk identification is lessons learnt from previous projects. The following areas are considered as sources of risks as shown in Figure 4-26 [Heinemann E, 2005]:

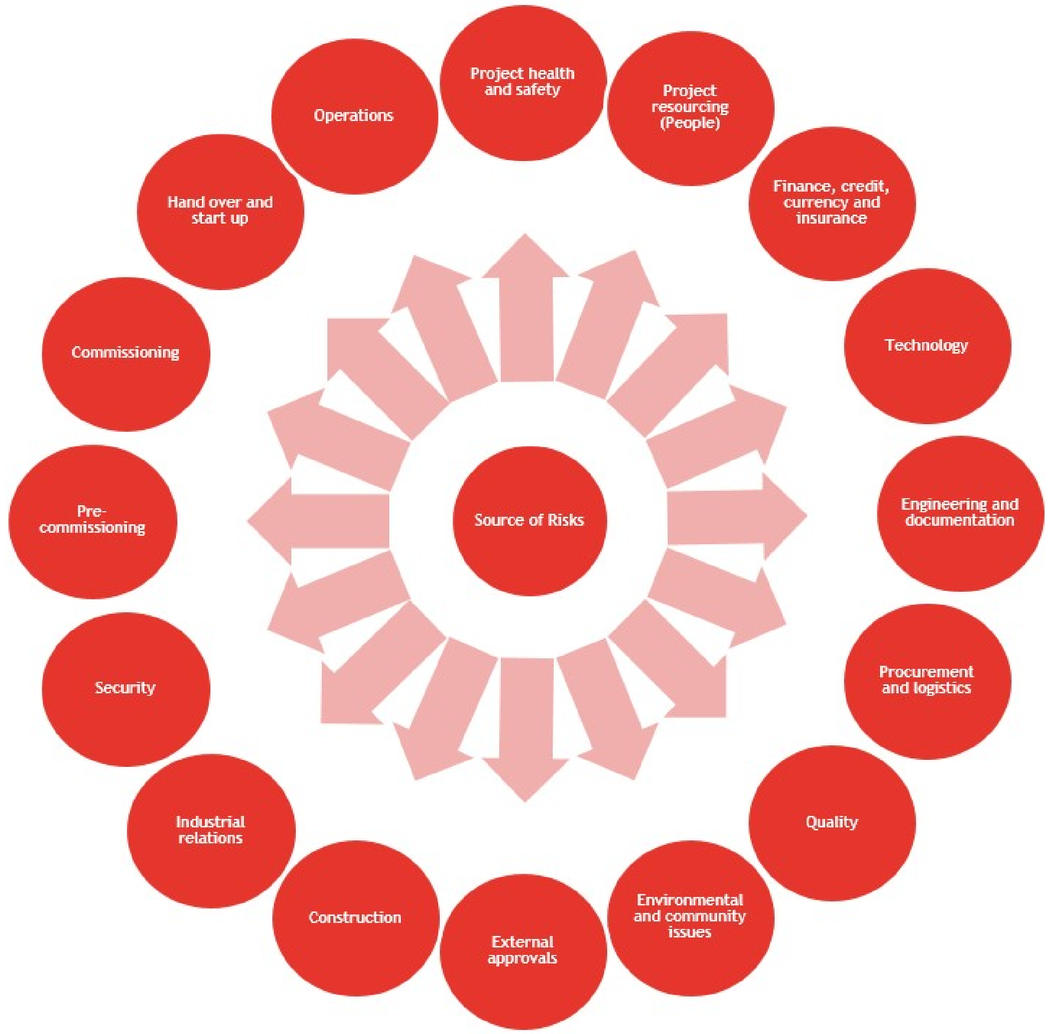


Figure 4-26 Source of project risks

The identification process begins with multi-functional risk assessments attended by as wide a range of participants as possible during the earlier stages of the project. This process tends to result in a large listing of potential issues with widely varying impacts, resulting in an extensive risk register that cannot be effectively assessed or tracked. It is very important to ensure that the design process strives to reduce all generic and lower level risk issues. This is completed through the generation of activities such as complete design criteria documentation for use by the engineering team and contracts & procurement documentation and procedures for that area. The initial risk issue and event listings are retained as a checklist to be used in the development of project execution and HSEC management plan.

4.11.1 Risk Management Plan

The objective of a risk management plan is to define how the project team coordinates risk activities and ensures that control actions are tracked and closed out so that risks meet established tolerability criteria. The purpose of the plan is to document how the team will meet this objective by identifying, analysing, evaluating, monitoring, and controlling project development risks. The content of the risk management plan is project specific and aligned to the business drivers, scope, and execution risks. It is also a concise document that focuses on outlining how the corporation and the project team will conduct the risk management activities in the most efficient and effective manner to the standard of the company. It outlines the risk management approach and methodology and defines accountability and ownership of different risks [Mochal T. Mochal J, 2007].

The risk management plan is maintained for the entire duration of the project. The structure and content of the risk management plan are as shown in Figure 4-27 [Vargas R, 2008]:

FIGURE 4-27 Typical content of the risk management plan

- Scope of the plan
- Strategy and objectives
- Key performance indicators to assess the performance of the risk management function for the project

- Organization, roles, and responsibilities for all key risk management positions
- Methodology, the approach, and tools to be used
- Processes including controls, procedures, reviews, and audits to ensure the risk management scope of activities are achieved
- Risk workshops, schedule of expected risk workshop, methodology and typical attendance
- Risk meetings, frequency, and attendance for risk meetings
- Risk register, the updating process for register, management action plan and other deliverables
- Implementation of the plan, resource & schedule requirements for implementing the risk management plan
- Reporting and software tools
- Self-assessment defines the process, tools, and performance standards to be adopted across the project to ensure risk management processes are effectively applied across all project aspects.

4.11.2 Risk Register

All risks are recorded in a risk register. It is critical to distinguish between risk categories and risk events. It is also advisable to list risks in categories like business risks, technical risks, and construction risks and rate each category. As illustrated in Figure 4-28, in the establishment of a risk register, the following information is included as a minimum [PMBOK Guide Fifth Edition, 2013]:

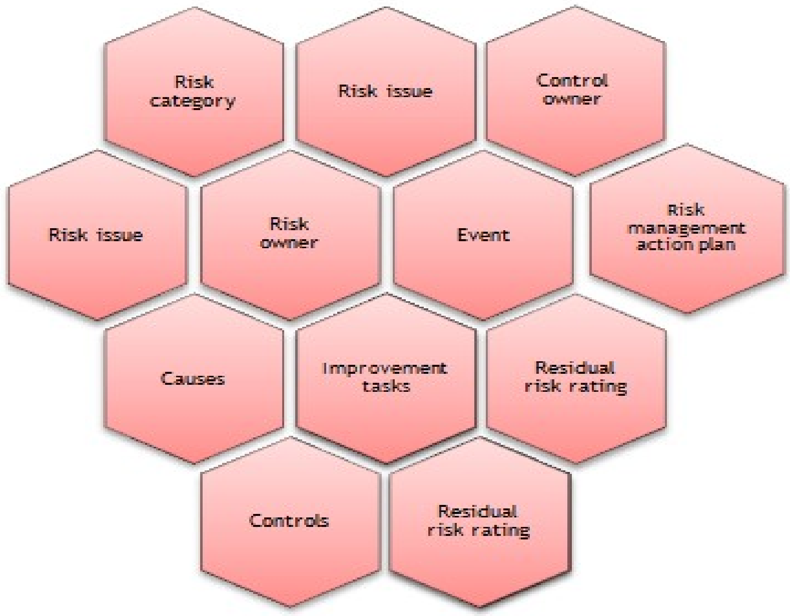


Figure 4-28 Typical content of Risk register

- Risk category
- Risk issue: description of the characteristics or circumstances that could affect the achievement of the business objectives.
- Risk owner: accountable person to make sure risk issue is managed
- Event: description of an occurrence or circumstance that is being analysed
- Causes: the causes that can give risk to the event. Root and direct causes are specified
- Impacts: impacts if the event occurred. Impacts correspond with the impact types in severity table
- Controls: existing planned and budgeted controls that are in place to manage the risk. Controls are specified as being preventive or mitigating controls. Causes and impacts are linked to controls to ensure there is no control gap.
- Control effectiveness rates: rating of control effectiveness calculated from the self-assessment process of critical control
- Residual risk rating: product of severity and likelihood factors after mitigation
- Improvement tasks: a list of further actions or additional works required. These

actions will include improvement tasks to improve an existing control, close a control gap or reduce severity or likelihood.

- Risk management action plan: a plan list of further actions or additional works required. These actions will improve an existing control, close a control gap, or reduce severity or likelihood
- Control owner: the persons responsible for carrying out the risk control actions.

The application of risk control measures has the potential to impact on the scope, schedule, and cost of the project. The proposed risk control measures are subject to cost benefit analysis and require formal approval processes prior to implementation. These actions are undertaken in accordance with the specific project management procedures.

Conversely, when a major scope change to a project is proposed, a risk assessment is carried out prior to introducing the change. This process includes a comprehensive review of all risk deliverables to ensure that all aspects of risk are accounted for. Risk assessment and management is a critical component of managing change on a project.

4.12. Health, Safety, and Security

All clients under the Health and Safety at Work Act 1974 should:

- Provide a safe entrance and exit to the workplace
- Provide a safe place to work
- Provide and maintain safe machinery and equipment
- Provide employees with the necessary training to be able to do their job safely
- Have a written safety policy
- Ensure safe handling, transportation and storage of machinery, equipment, and materials
- Provide personal protective equipment (PPE)
- Involve trade union safety representatives, where appointed, in all matters relating to health and safety

In all study phases, all fieldwork (e.g. construction pre-commitments or early works, baseline studies, geotechnical drilling, etc.) is conducted to execution phase standards and under an approved HSEC management plan specific to the project activities. Effective HSEC management is integrated in the way company does business including the delivery of capital projects through all phases of the project life cycle [Ritz G, 1994].

Supervisors have accountability for ensuring the successful execution of a project and for achieving HSEC targets and objectives. The involvement of project and contractor management teams in the implementation of these key elements forms the foundation for the success of the project.

An established and maintained HSEC culture helps employees and contractors at all levels adhere to the highest practicable standards for safe performance and the protection of the environment, employees and the people in the community in which the project will operate. The objective is to continuously strengthen the project by aligning the project objectives with the HSEC standards.

A HSEC management program established and implemented in an organisation with a strong HSEC culture flourishes as it is continually strengthened and reinforced by management decisions and actions. A HSEC management program established in an organisation without a strong HSEC culture rapidly loses focus as it falls prey to other conflicting priorities.

The HSEC culture is achieved by multiple inputs, which can be classified under people, practices and the work environment.

People are the foundation, with leadership taking on the key role of setting up the structure, which fosters a materially safe culture. The structure comprises the practices and work environment and is set up during the study phases. The level of effort invested at the early stages of setting up and implementation determines the final level of success and includes the following work during study phases [Bhp PDM, 2011]:

- **People:** Determine the level of expected H&S competence of the workforce to be mobilised and generate training material specifically aimed at closing the gap between the existing level and specific expectations in terms of delivery on practices and work environment.

  Leadership commitment is the most basic and essential element of any program that aims to achieve excellence in HSEC performance. It is important that actions begin with the project director and extend down through each management or supervisory level in every functional department (particularly for safety, line supervisors understand and acknowledge their responsibility and accountability for ensuring the safe operation of project activities). While it is commonly recognized that leadership at all levels is integral to success, it is critical that senior management demonstrate visible leadership commitment and encouragement wherever possible. Key HSEC responsibilities for each discipline manager as part of the management team include:

- Establishing and maintaining the structure of practices and a safe work environment.
- Mobilising a workforce with required training, experience and skills and provide targeted training to bridge the knowledge gap.
- Implementing a people based, or behavioural based, safety program.
- Establishing and maintaining the culture by way of the above input actions.
- Reviewing and authorising key management standards and initiatives.
- Committing sufficient resources to achieve the HSEC objectives.
- Ensuring involvement from all employees.
- Establishing clear accountabilities.
- Participating in audits and reviews.
- Setting up and establishing an internal communication plan to ensure that all employees on the project, the asset where the project is executed and stakeholders within the company and joint venture partners are kept up to date with project developments.
- Leading by example.

The HSEC management plans detail specific initiatives that the leadership group implements to demonstrate visible leadership, while the implementation of these programs represents a good leading indicator of the success of the project in H&S terms. The plan details the training programs that will be implemented to support the continued development of the leadership group.

The implementation of a people based, or behavioural based, safety program considers the variable levels of experience of contractors in this regard and commences with a rollout at leadership management level to facilitate gradual immersion. The full leadership team, followed by the workforce, is involved on a ‘coached’ basis to develop the people-based safety approach down to peer on peer observation level. The management leadership team remains engaged throughout the project execution phase and applies the program as a key to engage with the workforce and to demonstrate care and visible leadership.

An organization is expected to have:

- A strong HSEC culture.
- Mates looking out for mates.
- Full employee involvement.
- Active lines of two-way communication.
- Strong teamwork.
- Current documentation e.g. drawings, procedures, records etc.
- Practices consistent with documentation.
- Excellent housekeeping.
- Employees that have pride in the project and the way that it performs.
- An environment of high trust.
- Employees that are effective ambassadors within the community.

- **Practices:** Review the implementation contractor procedures to ensure that it covers project requirements and complies with the relevant HSEC regulations and incorporated standards. It is a requirement of leadership and the workforce to ensure compliance with Health and Safety legislation as outlined in below:
    - Leadership
        - Understand and ensure implementation of incorporated standards
        - Ensure procedures and safe work practices are aligned with standards
        - Set a clear accountability in terms of HSE
        - Ensure appropriate training and ongoing sharing of information and learnings
        - Provide adequate supervision, PPE, and resources
        - Identify, assess, mitigate, control, and monitor risks

- Workforce
  - Take reasonable care of own HSE and that of workmates
  - Apply procedures and safe work practices
  - Risk assess and mitigate safety of environment and work process on ongoing basis by way of job safety and hazard analysis
  - Apply due diligence to training and information provided
  - Comply with the legal instructions from supervisors
  - Wear PPE and maintain equipment in safe condition

- **Work Environment:** The work environment is the visible benchmark that sets the level of HSEC performance on the project. The work environment is reviewed to ensure that it sets the right example and facilitates a safe and healthy workforce. The permit system is also reviewed to ensure fit for purpose and enables safe access. The work environment should be designed to avoid or minimise the risk of environmental impacts.

The risk management process is a key tool used to identify and assess the risks and gaps associated with People, Practices, and the Work Environment. This is captured in the respective HSEC management plans, which are live documents, progressively developed during all phases of the project. The Environmental and Community management plans also incorporates environment and community as follows:

- **Environment:** The Environmental Impact assessment is a legislated requirement which commences early in the identification phase study to determine all statutory approvals and documentation required to implement the project [Smith N, 2002].

  The Environmental Management Plan is developed to ensure all requirements as identified in the Environmental Impact assessment are satisfied. This plan is underpinned by individual contractor environmental management plans to ensure aligned implementation. In addition to the Environmental Impact assessment and Environmental Management Plan, projects should also ensure compliance with the Environment standards in the context of the project. This may mean ensuring that project design seeks to avoid from the outset environmental impacts, and where this is not possible, minimisation measures should be designed-in to comply with regulatory requirements and stakeholder expectations.

- **Community:** organizations conduct social impact and opportunity assessments as a standard practice across projects and businesses. The community is engaged as early as possible as part of the social impact and opportunity assessment to gain their views and input. It is important to identify and engage all community leaders and stakeholders as appropriate. The community is a key stakeholder and to ensure appropriate engagement.

It is a requirement of leadership and the workforce to ensure a safe work environment as outlined in below:

- Leadership
  - Ensure existing and new construction areas are in safe and tidy condition
  - Ensure clearance to work permit process is effective and implemented
  - Understand and mitigate risks in environment
  - Ensure equipment registers are in place and audited
  - Ensure commissioning and testing complies with standards
- Workforce
  - Ongoing housekeeping
  - Apply clearance to work stipulations
  - Identify and mitigate risks in environment on day to day basis
  - Communicate changes in risks to mates and supervision
  - Inspect equipment daily and keep registers and records up to date
  - Undergo verification of competence tests as required

4.12.1 HSEC Risk Assessment and Register

HSEC risk assessments are conducted through all the phases of the project life cycle with the objective to identify material HSEC issues associated with the current, as well as future, phases of the project.

The risk register crystallises all material risks out of the risk assessments, with potentially fatal risks and risks with high probability and impacts reflected in the HSEC risk register.

Organizations should focus on the risks embedded in the project if the workforce out there can answer the following questions:

- What is it that can kill or seriously injure you in the task that you are doing, or about to do, today?
- Could anything you are doing, or about to do, cause serious injury or fatality to people working nearby or on the same system?
- What controls are in place to prevent that from happening?
- How do you know that these controls are in place and are effective?

Risk management is a live process throughout every phase of the project i.e. new risks become apparent, known risks change and mitigations must be adapted accordingly. The risk register is therefore reviewed on a regular basis by a representative leadership team to capture these changes. This review includes the following steps:

- Identification of new risks.
- Identification of changes to known risks in the register.
- Identification of mitigations or changes to mitigations for the above.
- Review of progress of implementation of mitigations.

The risk management process is also a key decision-making tool, which quantifies the risk aspect of various options when compared. This is not just useful during the selection phase, however throughout all phases of the project when decisions must be made based on relative cost, schedule, and risk basis.

Establishing the context of the risk assessment is one of the fundamental building blocks of the process and is needed to define the scope of the risk assessment. In doing so, it:

- Establishes the organisation and project environment in which the risk assessment is taking place.
- Specifies key objectives and required outcomes.

- Engages appropriate stakeholders in determining the risks and responses.
- Specifies criteria that allow the stakeholders to measure the success of the project.
- Defines a set of key elements for the workshop that assist in ensuring key project areas are covered.

The outcome from the risk assessment process is captured in a HSEC risk register that is the cornerstone for the successive development and implementation of HSEC management on the project. Many of the elements of HSEC management are contingent upon the outcomes and results from the HSEC risk assessments.

The outcomes from the risk assessments conducted during the study phases are taken into consideration in the development of a HSEC specification that is issued to all stakeholders such as the implementation contractor. On the other hand, execution phase risk assessments focus on the processes applied by the implementation and construction contractors.

The study phase risk assessments focus on the following:

- Risk assessment for the execution phase.
- HAZID, HAZAN and HAZOPs for the scope being engineered.

During the execution phase, the risk assessments by contractors, covering their activities and scope of work, are the most critical aspect in the development of their respective HSEC management plans for the project. The review of risk assessments submitted by contractors as part of the tendering process is important to ensure an effective approach for execution by the contractors. The use of the control self-assessment toolkit is also used as a basis to assess whether the contractor's risk assessment is appropriate.

Contractors conduct risk assessments at the following phases:

- Tender phase risk assessments: These assessments are reviewed by the project team to ensure all requirements as set out in the HSEC specification have been taken into consideration by contractors.
- Execution phase risk assessments: All activities of contractors are covered by risk assessments.
- Continuous risk assessments: During project execution, various forms of continuous risk assessments are implemented such as toolbox talks, start lists, job safety assessments and crew talks. The basis for of all these tasks are to ensure that work

crews are familiar with the tasks at hand, the risks and the mitigation measures to reduce the risks.

It is essential to communicate the risk assessment contents in an appropriate format with the workforce to ensure that it is captured in the job safety assessments.

Risks that have been identified and require control after any risk assessment are controlled through the preferred order of control methods known as the hierarchy of controls. The hierarchy of controls is depicted in Figure below [CPWR, 2012].

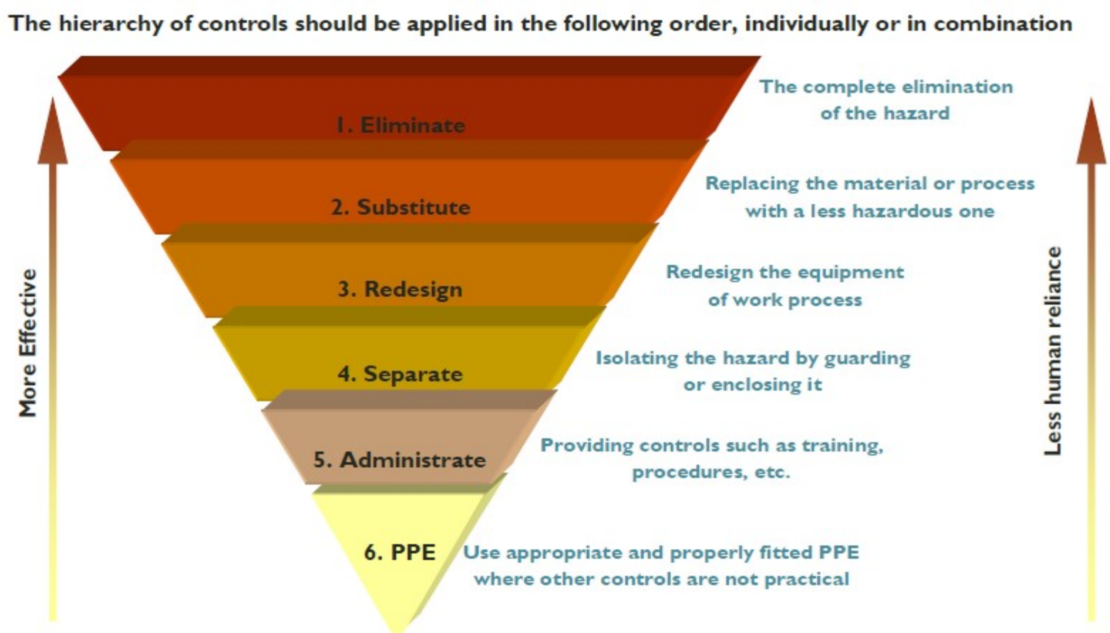


FIGURE 4-29 HSEC- The Hierarchy of controls

4.12.2 Health & Safety Management Plan

A clear concise and comprehensive study H&S management plan articulate how the project team implements the study activities and achieves the goal of excellence in HSEC. The study phase H&S management plan are developed prior to commencing any study phase activities.

Fundamental to development of the plan(s) is an understanding of the study scope and the risks associated with the study activities. Risk assessment workshops are conducted to focus the team on the study activities and document the associated risks and risk controls. The results of the

HSEC risk assessments form the basis for the plan(s) in the study phase. The plan(s) ensures that mitigation and control measures identified in the HSEC risk assessment process are implemented in a systematic way. A process of auditing and monitoring the effectiveness of these controls also forms part of the plan(s).

The need to recognise separation between the study phase H&S management plan and the execution phase plan has been highlighted with a number of significant incidents occurring in the company during study phase activities in the past, including fatalities. Project teams in the study phase tend to lack the heightened awareness that is associated with the execution phase activities and there is a need for strong leadership to maintain team focus. It is common that study phases will include activities that are not encountered in the execution phases e.g. establishing fly camps in remote areas [Bhp PDM, 2011].

The study phase plan(s) will include provision for establishing the safe culture, the leadership commitment and processes for auditing and measuring performance.

It is typical that activities conducted by the study team include interfaces with existing management plans e.g. if sampling is being undertaken on an existing site or for engineering in an existing office. Whilst it is appropriate that the study plan(s) references existing documents, a study plan is still required, nevertheless. Furthermore, it is essential the plans integrate appropriately.

Project teams cannot assume that existing management plans will be suitable to mitigate risks associated with study phase activities. Project teams tend to be itinerant and exposed to varying cultures when compared with a steady operations team. This requires over-emphasis on particular risk areas to ensure the project team members are aware and prepared for those risks.

It is essential the plan(s) covers any pre-commitment field activities at a detail level as if the project was in the execution phase. The structure and content of a typical productive safety plan(s) includes coverage of topics as summarized in below [Mol T, 2003]:

- Purpose and context
- Policy and supporting documentation
- Risk management
- Responsibilities and accountabilities
- Targets and metrics (KPIs)

- Induction and training program
- Safety communications and awareness
- Work environment including office safety plan, fitness for work, office security, emergency responses, and pre-employment medicals
- Safe site work environment
- Review permit system
- Hazard Reporting
- Management of changes
- Safety in design
- HSEC specification
- Contractor selection, alignment, and mobilization
- Review of procedures and safe work practice
- PPE
- Audits and review
- Health risk management
- Safety risk management
- Travel and traffic management
- Kick off meetings
- New starter process
- Daily workplace inspections
- Health and hygiene
- Manual handling
- Incident management
- Fatigue management
- Implementation schedule

The project gives careful consideration as to what level of data management is required to support the projects objectives. For example, where will incidents be recorded, how will distribution be affected, how will the tracking of actions be implemented etc. In particular, the behavioural observations, audits and reviews, workplace inspections, incident and hazard reports will generate a significant number of actions that need to be recorded and tracked to completion, how this is to be completed needs to be considered and the appropriate infrastructure and training identified prior to the commencement of execution.

Having a best practice HSEC management plan will not guarantee a successful HSEC performance. The plan is as only as good as the effectiveness of its implementation. The project team tracks the implementation progress of the HSEC management plan to ensure the plan is fully established early in the execution phase. The implementation plan is a structured program of tasks required to embed the HSEC management plan for the project. Each task is progressively actioned, and the progress reviewed by the project leader.

After implementation of the HSEC management plan and all risk mitigations, as foreseen during the study phases, the focus shifts to ongoing controlling and monitoring to ensure that the plan stays on track. The relevant OHS Act and incorporated standards of most countries contain specific legislated requirements with regards to controlling and monitoring.

It may also be required to implement specific interventions as the project progresses and the HSEC management plan is updated accordingly to ensure it is a live document up to project completion.

Trends in health and safety lead and lag indicators provide early warning signs to the project on potential major issues. Where trends are poor and lag indicators, it is necessary to document and implement a health and safety improvement plan. Poor trends are warnings that the project's HSEC management plan is either inadequate or the plan is adequate, though the project team has failed to effectively implement it [GHD. PPM Sec 18, 2011].

The corporation has documented experience whereby high-quality improvement plans once implemented, have improved significantly poor trends in a project's HSEC performance.

4.12.3 Environmental & Social Impact Assessments and Plan

The Environmental impact assessment and social impact and opportunity assessments are key legislative requirements, which are prepared during the study phases of the project and in many cases are on the critical path as it normally supports the application for regulatory approvals required prior to project execution commencement. It is typical that projects need to obtain an authorization from governing authorities prior to commencing any field activities.

The project management team ensures that as a minimum the following are considered [Fewings P, 2005]:

- Greenhouse gas emissions and mitigation options.
- Climate change vulnerability and adaptation requirements
- Energy use, minimisation, and efficiency.
- Biodiversity impacts and management and mitigation options, including both flora and fauna.
- Impacts to land, freshwater and marine environments.
- Water supply, usage, and management.
- Waste generation, recycling, and disposal.
- Air emissions.
- Noise and vibration.
- Cumulative impacts and management options.
- Indirect impacts and management options.
- Other beneficial landscape/seascape values.
- Product stewardship.
- Cultural heritage.
- Local employment.
- Accommodation.
- Local business opportunities.
- Community development/resettlement.
- Stakeholder communication.
- Accountability.

A proper Environmental and Social Management Plan (ESMP) should consider the following, at a minimum [World Bank, 2018]:

- Assessment and management of environmental and social risks and impacts
- Labour and working conditions—decent work and gender
- Resource use efficiency
- Pollution prevention and management
- Community health and safety
- Biodiversity, ecosystems and habitat conservation, and sustainable management of living natural resources
- Indigenous peoples and traditional local communities
- Cultural heritage
- Land acquisition, restrictions on land use, and involuntary resettlement
- Land rights, resettlement, and displacement
- Financial intermediaries' need for reports on compliance
- Stakeholder engagement and information disclosure

In addition, key considerations in the management of the EIA and social impact and opportunity assessment process are as follows:

- Benchmark processes and lessons learnt from other EIA and social impact and opportunity assessment processes.
- The boundary of the EIA and social impact and opportunity assessment process should be broader than the immediate project itself and consider at a landscape/seascape and catchment level not only direct project impacts however cumulative impacts (from adjacent activities) as well as indirect impacts and associated management options.
- Establish an external affairs function to manage interfaces with key stakeholders, e.g. the community, government, and media at a site level, in partnership with Group Public Affairs.

- Appoint a service provider with adequate experience in the host country in conducting and/or managing the EIA and social impact and opportunity assessment processes.
- Appoint a service provider with an understanding of the legislative processes in the host country to identify all required permits, licenses, and the average time it takes to obtain these. Establish a register with all required permits and licenses required and track the progress on a regular basis. This provides the project an understanding of when to commence the EIA and social impact and opportunity assessment process in order to meet the required deadlines.
- Commence baseline environmental monitoring as soon as reasonably practicable and ensure the scope of this supports the EIA and social impact and opportunity assessments.
- Ensure consistency of arguments between different specialist areas. The service provider responsible for the management of the specialist areas plays an important role in ensuring this.
- Ensure that the mitigation of high significance impacts is effectively understood and translated to all key stakeholders.
- Communicate to stakeholders how their concerns have been addressed. Transparency in the process is the key to success in the management of community stakeholders.
- Investigate whether a legal review is either required or recommended. If so, carry out the legal review.

Identifying and analysing long term social impacts as part of the study phase is critical to ensuring the long-term sustainability and viability of the operation in the region in which the project has been implemented. To contribute to the economic and social development of the region, consideration is given to maximising employment and contract opportunities for local employees and businesses.

It is recognised that not only technical factors, but also people, have an influence on the success or failure of a project. The engagement of stakeholders, such as communities in which the project is implemented, is important to establishing community growth strategies. The social aspect of licence to operate is built on ongoing stakeholder engagement in an environment of trust and integrity.

It is common practice to help create a community committee, which consists of recognised leaders from the community to represent them in forums. Regular meetings are set up with the committee and interested community members.

An Environmental management plan is developed to ensure all requirements identified are satisfied. This document clearly defines the actions the project will implement to meet the mandatory requirements that are detailed within the EIA and any associated regulatory approvals.

As part of the engineering design environmental design criteria must be developed and implemented by the design team. The engineering design environmental criteria shall apply the permit conditions as approved.

The following is typically taken into consideration when developing and approving an environmental management plan:

- Ensure that the plan meets the requirements of environment and community.
- This plan is reviewed and maintained on site by the environmental management representative.
- The document is a dynamic “living” document (system) and is managed as such on an ongoing basis up to contract closure.
- Ensure that it is clear within the plan what actions are required and who is responsible for implementation.
- The management plan outlines the processes undertaken to engage contractors, reporting requirements and links to reference documents.
- Ensure that it includes a waste management plan for the execution phase.

Below Figure shows a diagrammatic representation of the structure of the environmental management plan based on the ISO 14001 principles [EMP, ISO 14001]:

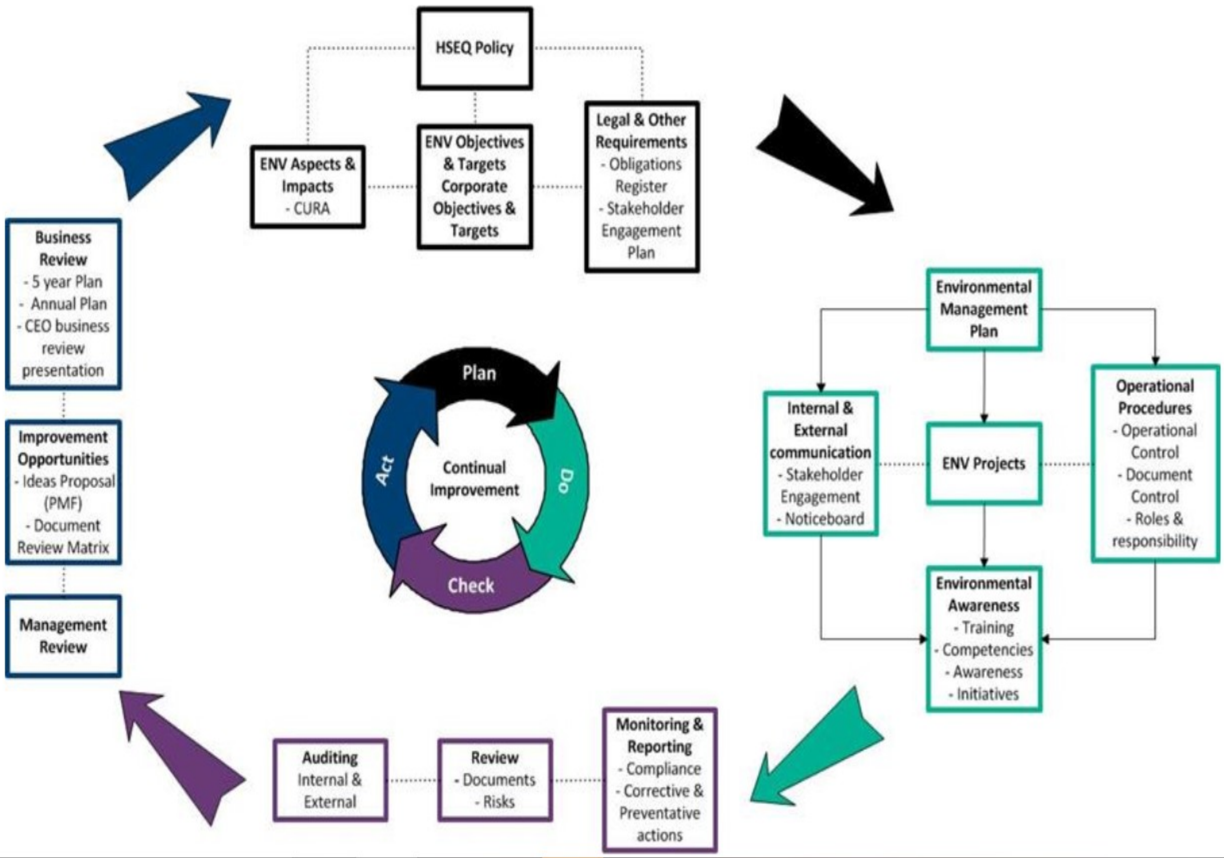


Figure 4-30 Environmental Management Plan

It is important to capture the HSEC lessons learnt progressively during a project and ensure these are included in the project close-out report [Rowlinson S, 2004].

Independently facilitated workshop sessions with key stakeholders provides for neutral ground during which the concerns, problems and gaps in the processes implemented during the phase of the project are identified and recommendations to improve are made. The objectives of such a workshop include:

- To review the level of implementation of the HSEC management plan.
- To review HSEC management strategies used on the project to achieve the project goal of material safety.
- To review strategies which were not successful, or which can be improved to ensure they are more effective.
- To discuss other strategies that may be useful in the future.

- To ensure that lessons learnt are transferred to other projects so that other projects can also achieve a high level of HSEC performance.
- Examine safety and environmental incidents, community complaints and responses.

4.13. Project Execution Plan

The Project Execution Plan (PEP) is a live document that describes how a project is executed and represents the project team's current thinking on strategy and tactics to be used to progress the project and mitigate project risks. The formal documentation of the PEP provides significant value in detailing and formalising the planned approach, enabling effective communication between stakeholders and is a tool to minimise the effect of project team member turnover [PMBOK Guide Fifth Edition, 2013].

During the SPS, a project execution strategy is developed to define how the project will proceed through to execution. This strategy is a critical project planning process, which identifies the drivers of project success and the risks to the project.

This strategy forms the basis for the development of a full PEP by the end of the definition phase. At the definition phase the PEP highlights the reasoning for the approaches to be adopted for the execution of the project, and clearly defines how the project is executed. The PEP will define and summarise the key parameters and performance indicators included in the SPS.

It is paramount to ensure that the parties engaged in the execution phase are actively involved in the definition phase to ensure ownership of the project scope and the execution plan (the project outcomes).

The content of the PEP is project specific and aligned to the business drivers, project scope and execution risks. The complexity and depth of the PEP reflects the size, complexity and risks associated with the proposed project being studied.

There is only a single PEP for the project which recognises the roles and activities of the client `s team, the implementation contractor, consultants, contractors and external parties. It is critical that it addresses the full scope of the project and is the basis of executing all tasks and activities required to deliver the full project scope.

The PEP addresses the project team's plans to execute and manage the full scope of the project. The key planned activities i.e. engineering, procurement, construction, commissioning, handover and close-out form the core of this plan. The two most important responsibilities of a project manager are planning and the integration and execution of plans [Kerzner,H, 1989].

The PEP will also address how the integration of these activities will be managed and how the other key processes will be managed (i.e. management of scope, cost, schedule, quality, human resources, communications, and risk). The PEP will cover [Lipton S, 2002]:

- **Project Objectives:** a clear statement of the objectives including business drivers, capacity, timing & quality is formatted as a "Mission Statement" or "Project Objectives Statement". The PEP will contain a summary statement on key criteria and performance parameters to be achieved on the project with references to the appropriate detailed documentation.

- **Project Scope:** the main packages of scope for each stage of the project to be completed during the execution phase will be documented. Any scope not included in the project should be clearly identified. These could include items or scopes of work provided by external providers such as the government or contracted suppliers. The battery limits to the overall project scope and between individual key components of scope should be clearly identified and documented.

  In this regard, supporting documents are:

  - Statement of Requirements: this will detail product specifications, availability, quality standards and nominate the relative priorities of cost, schedule, and other operability outcomes.

  - Scope of Work: The PEP provides a high level overview of the project scope. This will include any scope being executed by others and clearly indicate the battery limits and any exclusions.

  - Work Breakdown Structure: the basis of the project WBS and a high-level overview of WBS should be documented to clearly communicate the overall structure and grouping of deliverables.

- **Contracting Strategy:** The PEP will communicate the execution strategy for the project and namely how to execute the scope and the contracting strategies proposed. There may be a variety of contracting strategies covering third party design and technology. The contracting strategy also documents the background and decision process for the specific strategies selected.

- **Project team organization:** The PEP documents an organisation chart for the client team, the engineer's team, implementation/construction teams and commissioning teams. The team structure will be aligned with the selected contracting strategies and project risk profile. It will specifically outline:

- Documentation on specific project team roles and responsibilities. The descriptions shall include specific responsibilities such as management of special risks and a matrix of authority levels.
- Attention is given to the alignment of the project team with their roles and the project objectives.
- Strategic measures to retain key personnel.
- The recruitment/assignment of personnel, procedures for engagement, any special terms and conditions of employment, mobilization, and accommodation issues.

▪ **Health & Safety Management:** The PEP provides a high-level overview of H&S management requirements. It will specifically outline:

- The policies to achieve the project health and safety objectives.
- The resources required to support the policies and programs.
- Project access and security management plan.
- "Fitness for work" policy, and
- Any identified health risk and the planned mitigation strategy.

▪ **Environmental and Community Management:** provides a high-level summary of the E&C management requirements. It specifically outlines:

- The policies that will be used to achieve the projects E&C objectives.
- The resources required to support these policies and programs, and
- Any identified risks and the planned mitigation strategies.

▪ **Licenses, Permits and Statutory Approvals**: provide a register of all permits and licences required including the issuing authority and the nominated single point accountability in the project team. It documents the application and approval process including the timing, resources, data, and costs required to gain the permits. It also provides an assessment of the expected conditions to be imposed with the permits and the likelihood of approval.

- **Project Risk Management:** The PEP provides a high-level summary of the risk management plan. It specifically outlines:
  - A comprehensive execution phase project risk registers with risk exposure, control & mitigation measures and nominated responsibilities.
  - Risk review and management procedures to be used during the project execution.
  - Documentation outlining how the changing risk profile over time will affect the forecast contingency requirement, and
  - Documentation outlining the insurances and the extent of cover.
- **Engineering Management:** the PEP provides a high level summary of the Engineering Management Plan. It specifically covers:
  - The Basis of Design
  - Technology Management
  - Engineering systems and tools
  - Applicable Engineering Standards
  - Management of Vendor Documentation
  - Use of third-party consultants
  - Plan for engineering covering in-house & outsourcing
  - Engineering reporting and progress assessment, review and approval process (safety in design, operability, maintainability, reliability, constructability)
  - The use of new and proprietary technology and the associated the risks
  - Outline of field engineering support plan, and
  - Define the plan for transition from engineering into commissioning, handover and start up.
- **Contracts and Procurement:** high level summary of the contracts and procurement plan specifically outlines:

- The procurement plan and schedule for contracts for offsite fabrication, onsite construction, supply of bulk materials and equipment purchases:
- The procurement processes including specific roles and responsibilities and matrix of approval to make commitments on client behalf. This should also include any third parties
- Procurement policy and the approval process for pre-qualifying, tendering contracts
- Purchase orders, progress claims and invoices
- Procurement targets from local and international markets
- Specific project contract terms and conditions
- Procurement quality and expediting services
- Logistics plan
- The contract administration process
- The communications plan and protocols, and
- Define procurement progress assessment and reporting plan.

▪ **Construction Management:** The PEP provides a high-level summary of the construction management plan. It specifically outlines:

- The construction sequence
- Outcomes of the constructability review
- Construction coordination including shutdowns, access inspections and as built verification
- Construction resource requirements, construction supervision structure and resource numbers
- Availability of construction resources including source of supply and any related costs
- Construction progress monitoring
- Construction accommodation requirements

  - Site establishment and associated facility infrastructure
  - Industrial relations policy for the project, and
  - The process for the construction contractor meetings and reporting.

- **Project Control and Reporting:** The PEP provides a high-level summary of the control process addressing project cost control, progress measurement, schedule management, change management and reporting. It nominates the project control systems to be utilised for cost and schedule. It nominates the content, format, and frequency of external progress reporting. The PEP refers to the following documents and highlights any key issues to be managed:
  - The project master schedule including the basis of schedule, the critical & near critical activities, and the resource histograms for the main and critical activities, and
  - The summary of the cost estimate including the basis of estimate and the provisions for known risks, escalation, and contingency.

- **Quality Management:** The PEP provides a high-level summary of the quality management plan specifically covering a summary description of the quality management process to be employed and the internal and external resources required.

- **Communication and Stakeholder Management:** the PEP provides a high-level summary of the stakeholder management plan in particular:
  - The interfaces and relationships with third parties
  - The procedure for external stakeholder communication
  - The procedure for internal stakeholder communication, and
  - Document management system.

- **Information Management:** The PEP outlines the information and technology plan and in particular:
  - IT policies
  - Compliance with local and statutory legal requirements
  - The technology and systems for management of data

- IM roles and responsibilities
- Transfer of project information, and
- The information management specific induction and training requirements.

- **Operational Readiness:** The PEP defines the methodology for establishing the start-up operational capacity necessary for management, monitoring, and reporting activities against control baselines.
- **Commissioning Management:** The PEP provides a high-level summary of the commissioning management plan. It specifically outlines:
  - Responsibilities, and implementation strategies for the various phases of commissioning
  - The handover points to be adopted for transitioning from construction to pre-commissioning, this includes hierarchy of systems and the interrelationships
  - The requirements for handover of packages, and
  - Document roles and responsibilities of pre-commissioning and commissioning teams
- **Project Reviews and Audits:** The PEP outlines the plan for regular reviews and audits to ensure compliance.
- **Project Closeout:** The PEP outlines the closeout plan describing the processes for closing the project on completion. This will address:
  - The closeout of all purchase orders and contracts
  - The clean-up of site, and
  - The disposal of surplus materials.
- **Governance:** The PEP outlines any governance requirements and structures to ensure compliance with all relevant requirements.
- **Project Administration and Finance:** This documents how the project is administered with respect to office facilities administration policies and will clearly document how the Project Procedures Manual is compiled and the associated responsibilities.

5. ENGINEERING MANAGEMENT

5.1. Introduction

Engineering Management as one of core work process in the organization outlines engineering activities and the key engineering management processes such as development of strategy, engineering teams and basis of design. It also provides details on the development of the engineering management plan. In addition to this chapter, subsequent chapters such as procurement, construction, commissioning & ramp up require engineering involvement and will be referenced when required.

The engineering phase of a project commences in the initiation phase and extends throughout the whole project life cycle. The effectiveness of the engineering management processes undertaken impacts the quality, schedule, cost, and operability of the installed assets. Successful implementation of the engineering management process is therefore a key value driver for the project and a structured approach to management of this process is essential [Smith N, 2002].

The level of engineering definition for a project scope increases through the initiation phase to support the quality of the project estimates and schedule. The engineering and design phases, design basis, specification and scope of work preparation and issue processes from the framework for engineering management to achieve the baseline objectives of each project. The project execution plans and engineering activity plans will guide the engineering and design work. Activity planning reflects the engineering and design effort to establish a schedule, prepare a staffing plan, organizational chart, and deliverables list.

During the early phases of a project, several project alternatives are investigated and have preliminary engineering carried out to a varying degree to assess their financial and technical feasibility. In planning the engineering function, consideration is given to the opportunity framing and selection processes which drive the demand for engineering resources in early phases of the project development. The engineering processes are focused on the optimizing of the selected alternative and advancing engineering progressively. To gain efficiency in engineering through the project phases, uncertainty in the scope is eliminated during the selection phase enabling the engineering to progress on the selected alternative only.

The deliverables list will detail both estimated hours of effort required and estimated schedule for first issue. Management of deliverables and measurement of work progress is performed by the Project Manager in association with the Lead Engineers using computer tools & software for overall schedule of the works. These tools are managed by project controls with inputs from engineering. Engineering and design also involve the provision of inputs to project controls for estimating materials, equipment, direct and indirect labour costs, and time.

5.2. Engineering Management Plan

The engineering plan prepared by engineering manager expands the project plan in the areas relating to engineering, providing more specific information on the following topics [Kerridge A. Vervalin C,1986]:

- Engineering work scope
- Design basis for process units and offsites
- Engineering and design evaluations
- Maintenance, reliability, and flexibility needs
- Material selection criteria
- Engineering economics and design philosophy
- Design specifications and standards
- Applicable codes and regulations
- Equipment layout and plant arrangement
- Use of models
- Engineering problems specific to the project

5.3. Change Management

An accurate impact assessment of a proposed design change is essential to enable an informed decision of whether it is worth implementing the change to maximize efficiency in the design process and to prevent overruns. It is also suggested that relying solely on an individual's experience is not acceptable for two specific reasons [Hindmarch H. and Gale A, 2010]:

- There is a risk that the individual could make an incorrect judgment.
- Strategically, relying solely on an individual's experience will not add any value to the company, since when that individual is no longer employed by the firm, his or her

expertise will be lost.

Scope and design freeze are essential tools for effective delivery of engineering. The success of project delivery through effective scope and design freeze relies on the timely involvement, commitment, cooperation and support of all stakeholders, including project management, engineering and construction management.

The project execution team is collectively and individually responsible for developing the scope against the established baseline. The informed consensus of the stakeholder group is a prerequisite to establishing a sustainable scope freeze. To understand the baseline in order to effectively understand and control change, there must initially be a reference or baseline against which to measure.

The scope of work must be frozen as the key documents and drawings reflecting the scope of facilities are approved for Design (AFD). This should be achieved at the end of the DPS. The key documents & drawings defining scope freeze at AFD are [GHD. PPM Sec 12, 2011]:

- Basis of Design/Valid User Requirements Specification (VURS)
- Design criteria/Functional Specification (FUSP)
- Equipment list
- Civil general arrangements (site layouts)
- Architectural layouts
- Plant general arrangements
- Services general agreement
- Single line diagrams
- Process flow diagrams, and
- Piping and Instrumentation diagrams

AFD reviews may also be completed for key supplier data. This will be determined on a case-by-case basis. This review should allow a sufficient degree of freeze on major design elements to allow the discipline designs to continue without significant delays.

Battery Limits are also critical in defining SOW. This is particularly important during the course of DPS & execution phase work and it must be established and agreed between all parties to prevent duplicate work, or gaps in the design. Battery Limits will develop as the project progresses and should be regularly updated, discussed and models exchanged with each party involved [PMI Construction Extension to the PMBOK® Guide, 2016].

To minimize changes, once the defined scope has been reviewed, approved and frozen, there should be no need for change, provided that the design remains.

- Safe
- Functional
- Cost Efficient, and
- Legal

The project manager, engineering manager, engineers and designers, due to their knowledge of the project scope, estimates, budgets, and execution plan, are central in the identification and quantification of deviations. When any scenario occurs that could result in a variance from the current execution, estimate or schedule, the party identifying the deviation must initiate and manage the deviation process. They should be familiar with their scope of work and estimated hours' effort budgeted. They should also be aware of equipment and material costs and quantities included in the project cost estimate for their discipline and initiate the change process where significant trends or deviations are identified.

The identification and processing of engineering changes are critical to the maintenance and updating of the project forecasts, scope, estimates, budgets, schedules, execution, and staffing plans.

The construction professionals will widely agree on the benefits of having a good change

management system in its construction project management portfolio [Hao, Q. Shen, W., 2008]:

- Reduce the cycle time for construction changes
- Reduce the costs of change management
- Get a coordinated information flow and document flow
- Get better status on changes
- Improve resource utilization and co-ordination

- Bring engineers on different sites together to work on changes
- Obtain more accurate estimates of change costs and times
- Gain traceability or an audit trail of change activities
- Establish better control over the “as built” to make it conform with the “as designed” or
- the “as changed”
- Assist the managers in making “smart” decisions
- Best practices in change process are followed

The initial step in engineering change management is the notification of a potential change or initiation of a Design Change Request (DCR) or site instruction. The second step in engineering change management is the preparation of a Project Deviation Notice (PDN) that includes an estimate of engineering effort to allow the PDN to be approved. Design changes raised in a PDN, must not be progressed, or incorporated until the PDN has been approved by client. The consultant must then prepare a detailed statement of variation claim without delay.

Late design changes are high risk and are to be avoided (unless justified e.g. safety related design improvements, constructability, operability, cost or schedule). There are clear risks of delay to delivery, safety implications, and a high risk that not all design reviewers’ inputs will be fully considered.

Technical Queries (TQ’s) are strictly for technical issues and shall be managed and submitted by the Engineering Manager. TQ’s must appraise options available and make recommendations for client endorsement. Changes to the design may also occur as a result of questions or requests for information from the construction team at construction, modularisation and/or pre-assembly locations. Such changes are documented via a request for information, which are processed as per the relevant procedures Further, the impact of all approved changes need to be marked on the master (redline) set of drawings to support that effort.

5.4. Engineering Reporting

In support of the project manager and the engineering team, engineering planners from the project controls group are assigned to the project area to develop engineering execution plans, integrating activities/deliverables, schedules, and staffing plans to provide the engineering team with accurate and consistent reporting and analysis for forward-looking planning.

The following defines the suite of standard reports that are required to be generated by the engineering planners for each area at the given frequency as follows [Kerridge A. Vervalin C,1986]:

- Engineering Progress and Performance Report
- Engineering 3-Part Curves (Progress/Productivity/Manpower) Overall, by discipline and by office
- Engineering Summary of Deliverables/Activities and Hours
- Engineering Deliverables Status Issued for Review (IFR, IFD & AFC)

All project deliverables budgets, both direct and indirect, are coded and uploaded in the organization database by the project controls group. The system requires regular updates for the progress of their designated deliverables. This database within financial recording system will capture expended hours at the work breakdown structure sub-facility levels, which are used for performance/productivity reporting. All the necessary project and client reports will then be generated.

5.5. Engineering Quantity Management

The engineering quantity management practice defines the objectives and prescribes the general processes for engineering discipline management of equipment and bulk material quantities during the detailed engineering execution phase of a project.

The objectives of engineering material quantity management are to provide certainty in forward planning of equipment and material supply and installation by delivering engineering designs to established quantity estimates and to convey an early indication of significant potential deviations from expectations.

Engineered quantities are managed throughout the detailed engineering execution phase by the discipline originating the design, however, the quantities are tracked at a summary level for only key commodities.

Reporting provides the necessary feedback and forward-looking indicators for originators and other stakeholders affected by quantities to prepare in advance for potential changes. Quantities are reported in accordance with project controls quantity tracking and reporting practice.

The engineering team assigned to the project is accountable and responsible for the definition and management of material quantities throughout the detailed engineering design process, from receipt of AFD key documents to completion of AFC engineering deliverables. The below list represents the workflow to demonstrate that the engineering group responsible to action the HSEC and MTO elements of project delivery [GHD. PPM Sec 12, 2011]:

- Define Engineering Deliverables
- Freeze Design Basis and Scope
    - Define the scope of work
    - Hold Estimate Kick-off Meeting
    - Execution Plan
    - Fee Estimate
    - Engineering Schedule
    - Risk Assessment
    - Battery Limits
- Preparation of Engineering Deliverables
    - Preparation of Drawings
    - Preparation of Shop Drawings
    - Preparation Reports/Option Studies
    - Preparation of Calculations
    - Engineering Progress Report
    - Safety in Design (SID) Report
    - Revision Numbering
    - Interdisciplinary Review
- Equipment, Device, and Instrumentation Numbering
    - Equipment Lists and Numbering
    - Drawings Numbering

- Third Party Supplier Interfaces
- Preparation of Engineering Design Change Request (DCR)
- Engineering Design Reviews [Bent J. Thumann A, 1994]
  - Design Reviews
  - Quantity Tracking
  - Safety and Environment Reviews
  - 3D Model Reviews
  - Constructability, Maintainability and Operability Reviews
  - Technical Peer Reviews
- Revision of Engineering Deliverables
- Finalize Engineering Deliverables

5.6. Engineering Design Phases

The engineering works will be performed in the following study & execution phases. The scope and process will be as agreed with the client [Bhp PDM, 2011].

- **Identification Phase:** The purpose of the identification phase is to investigate several alternatives, through benchmarking and early engineering, and prepare high level capital estimates. To achieve this, work plans shall be developed for inclusion in the Selection Phase Study (SPS).
- **Selection Phase Study:** The purpose of the SPS is to identify and evaluate options including locations, type of equipment and type of facilities for client to make an informed decision and draft a strategy for the definition phase. Engineering assessment and details will be preliminary in nature and utilize standards and where practical replicate existing facilities. Cost estimates, option time durations, environment, heritage and community approval issues are also evaluated during this phase. Selection phase designs shall be prepared by Work Pack (WP) with the basis of design and preliminary general arrangements prepared, and the Value Improvement Process (VIP) commenced. WPs outline scope and budget and aid the control of the scope of work through the study reflecting engineering and estimating.

- **Definition Phase Study:** The purpose of the definition phase is to:
    - Allow all stakeholders to agree and sign off on the general arrangements of the process plant and supporting NPI
    - Define the plant area and the extent of NPI facilities and locations
    - Estimate the project capital cost to the specified level of accuracy as detailed in client standards for a definition phase study
    - Prepare sufficient engineering design and engineering strategy for a reasonably firm basis of the future design including material quantities, and scope of works
    - Develop General Arrangement drawings (GAs) of the plant area and NPI facilities to a sufficiently robust level that allows the positioning of major structures, general access, facility access, area interfaces, interfaces with existing equipment, drainage and major service routes
    - Prepare equipment list (all equipment numbering and descriptions to be signed off in this phase)
    - Prepare preliminary Piping and Instrumentation Diagrams (P&IDs)
    - Process Flows Diagrams (PFDs)
    - Prepare Preliminary single line diagrams, and
    - Develop preliminary details of interfaces and battery limits between process and non-process plant.

At this stage, engineering shall provide the constructability review team a set of drawings, which the EM approves as sufficiently developed, to conduct a preliminary constructability review. Engineering shall consult with the constructability review stakeholders prior to the preparation of Material Take Offs (MTOs). Standard equipment shall be identified as per standardized designs, strategic supplier agreements and preferred equipment lists. As per the SPS the definition phase designs shall be prepared by continuation of the development of WP. Engineering department at definition phase usually carries out following activities:

- In the project design development, where practical and where cost justified shall use modular construction, preassembly, and off-site commissioning techniques in the design of all infrastructures. The aim is to reduce the amount and complexity of on-site work and reduce the risk profile of site activities. The extent of standardization and modularisation shall be determined during the definition phase in consultation between the engineering, constructability, and operations teams. The standardized and modularized facilities shall be identified, compiled, and issued for approval by the client.

- The value improvement process is also conducted to maximize the return to the client when the definition phase has progressed sufficiently to ensure the review is meaningful.
- Engineering document review and approval will be performed to ensure correctness of engineering deliverables based on the approved schedule.
- A high level basis of design document that captures the physical description of the facility identified in the scope definition sections as well as operation and performance requirements, and handover criteria to measure success at project completion is generated at this phase.
- Early engineering is an initial "sub-phase" of detailed design in the execution phase and may be completed for a portion of all work scopes. Early engineering may be limited to the activities as set out below for specified scope(s), or it may include continuance with any or all the subsequent detailed design phase work. Prior to commencement, an engineering and design work breakdown delivery schedule and resource plan, in support of the overall project objectives, shall be established.
- 'Approved for design review' shall be conducted in order to verify the intent of designs completed as part of the DPS, formally providing approval for engineering design to commence, ensuring that all comments added to the DPS WPs have been addressed, ensuring that early engineering works have been completed, and ensuring that the standard discipline design criteria (e.g. civil, structural, mechanical, electrical, instrumentation and process) and any project specific design criteria have been updated, issued and approved.

When approved by client, the project scope is considered "frozen" and will become the baseline document for design development. Any change to AFD documents, namely the design basis (e.g. drawings/rates/design criteria/standards) require approval in the form of a design change request (DCR) and request for variation or potential deviation notice approved by the client.

- **Execution Phase:** Design basis documents in DPS shall form the basis of the execution phase which encompasses detailed design work. Below is the typical list of engineering deliverables at execution phase.

- **Engineering Calculations:** detailed design commences using AFD and supplier data as reference documents by all disciplines. Preliminary supplier data is obtained from the selected supplier of the equipment. Designers must develop interfaces at a level that allows for the potential that certified supplier data received later may differ from that initially supplied.

- **Design Documentation:** Documents, including drawings and data sheets shall be prepared in accordance with standards and agreed engineering technical document preparation procedures.

- **Progress Design Reviews:** A formal progress design review workshop should be conducted at regular such that all stakeholders have completed inputs to facility definition and enable the design to be, as far as practicable, frozen before proceeding. This workshop shall include standard design criteria, design calculations, drawings, 3D model review, comments/actions from AFD reviews, details & layouts of all equipment to be incorporated in the final design, general design issues, constructability, maintainability and operability and HSS issues.

- **Final Design Review:** Following the progress design review, the drawings shall be further developed and issued for internal inter-disciplinary squad check and subsequently to the client for their review. Comments included in the master mark-up files shall be reviewed for inclusion in the revised drawings.

- **Final Checking:** The design checker checks the drawings, considering design review comments have been addressed, access requirements to plant and facilities, set-out is correct for equipment interfaces, clearances and maintenance requirements, crane lift requirements, standard design criteria have been adhered to, and standard specifications have been complied with.

- **Quantity Tracking:** as the detailed design progresses, the engineering group shall monitor facility, scope, and quantities against the DPS baselines. Where there are specific identifiable scope changes these shall be handled via the normal change management process. The intent of these reviews is to identify trends between DPS and detailed design that have cost or schedule impacts and provide early advice of such changes.

5.7. Basis of Design

The Basis of Design BoD is a document that records the general business expectations, performance criteria and special requirements as they relate to space, site, and technical design elements. The BoD criteria is not intended to be a substitute for the Owner's regulatory or code requirements, standards and guidelines, or the design professional's project design drawings and specifications. The BoD simply includes both narrative descriptions and lists of individual items that support the design process documenting the primary thought processes and assumptions behind design decisions that were made to meet the project requirements.

The BoD document will typically be developed incrementally by the design professional as work on a project moves from Pre-Design to Design, and into the Construction Phase. The Content of the BoD document will vary from project to project and system to system, but in general it should have the following basic structure [The OFPC Project Management Manual, 2011]:

- Fundamental BoD Criteria
- Building Elements Lifespan
- Economic Parameter for Life Cycle Cost Analysis
- Architectural and Engineering Criteria
- Assumptions regarding usage of the facility
- Description of systems, components, and methods for achieving the design intent objectives
- Emergency power control and function
- Energy performance
- Expectations regarding system operation and maintenance
- Fire and life safety (criteria, general strategy narrative, and detailed sequences)
- Indoor air quality strategies and methods
- Information regarding ambient conditions (climatic, geologic, structural, existing construction) used during design
- Interior design and furnishings

- Listing of specific manufacturer makes and models used as the basis for drawings and specifications
- Manufacturers' catalog cut sheets
- Material, labor, and equipment maintainability
- Narrative state of operation that verbally details how the facility is expected to operate under various situations (such as normal operation, extreme event, emergency)
- Narrative statement of design that verbally describes how the designer intends to meet the OPR
- Performance criteria that the system was designed to meet – linked to the OPR
- Schedules
- Unusual or specific codes, standards, and guidelines considered during design of the facility and designer interpretations of such requirements
- Specific design methods, techniques, software used in design Stand-alone and integrated sequences of operation, including set points and control parameters
- Structure
- Availability, type, and location of existing utilities

Refer to the BOD procedures used by some lead Engineering Consultants; Designs shall be prepared based on the requirements set out in the following items:

- Safety in Design- SID
- HSE, Constructability, Operability, Maintainability & Sustainability
- Engineering Standard Discipline Design Criteria
- Industry Codes and Standards
- Standard Drawings and Specifications
- License, Permits, and approvals

5.8. Engineering Deliverables

The common list of engineering deliverables grouped by disciplines are as follow [Technip, 2014]:

- **General**
  - Engineering Design Data
  - Project engineering plan
  - Project Equipment list
  - Engineering document register
  - Engineering Progress Report
  - Calculations
  - Engineering Shop detailing
  - Revision Numbering
- **HSE**
  - Safety concept / Design Safety Philosophy
  - HAZID report
  - Fire Protection design specification
  - Fire and Gas detection design specification
  - Safety Integrity Level (SIL) review
  - HAZOP report
  - Fire water demand calculation note
  - Fire water Piping & Instrumentation Diagrams
  - Deluge system arrangement drawings
  - Firefighting and personnel protection drawing
  - Passive fire protection drawings
  - Quantitative Risk Analysis- QRA
  - Fire & Gas detection layouts
  - Fire & Gas Cause & Effects matrix

- Hazardous area classification drawings
- Health and environment requirements specification
- Environmental Impact Assessment
- Noise map Project engineering plan

- **Handling**
  - Handling equipment Layout
- **Equipment**
  - General specification
  - Technical Specification
  - Mechanical data sheet
  - Material requisition
  - Technical bid tabulation
- **Process**
  - Process Design Data
  - Process design criteria
  - Block Flow Diagram
  - Process flow diagrams
  - Process description and operating philosophy
  - Process equipment list
  - Heat and material balance
  - Process fluids list
  - Utility consumption list
  - Equipment process data sheets
  - Heat exchanger thermal data sheet
  - Duty specification

- Piping and Instrumentation Diagrams (P&IDs)
- Line list
- Emergency shutdown diagram
- Cause and effect diagrams
- Flare Report
- Calculations notes
- Operating manual

- **Plant Layout**
  - Plant Layout Design specification / Plant layout guidelines
  - General Plot Plan drawing
  - Key plan
  - Unit Plot Plan drawing
- **Piping stress analysis**
  - Piping flexibility and stress analysis criteria
  - Piping stress analysis Calculation note
  - Pipe support booklet
  - Supply specifications for pipe supports
  - Pipe support drawings
- **Piping Installation**
  - Piping Design Basis
  - Line diagrams
  - Piping layout drawings
  - Piping general arrangement drawings
  - Piping isometric drawings
  - Line list

    - Piping Material Take-Off
    - Specifications and bill of quantities for construction sub-contracts

- **Piping Material**
    - General piping specification
    - Piping material classes specifications
    - Supply specifications for piping materials
    - Piping Material Requisition

- **Civil**
    - Design specification / Basis of design
    - Grading plan
    - Foundation calculations note
    - Foundation drawing: Reinforcement
    - Foundation drawing: Formwork
    - Civil works specification
    - Standard drawings
    - Drainage calculations note
    - General Underground Networks drawing
    - Civil works installation drawings
    - Architectural drawings
    - Specifications and bill of quantities for construction sub-contracts
    - Building detail drawings
    - Steel Structure
    - Calculation notes
    - Steel structure design drawings
    - Civil Material Take-Off (MTO)

    - Steel structure standard drawings
- **Material & Corrosion**
    - Corrosion control and material selection report
    - Material selection diagrams
    - Cathodic protection system design specification
    - Painting specification
    - Insulation specification
    - Insulation material take-off
- **Electrical**
    - Electrical design specification
    - Electrical consumers list & power balance
    - General one line diagram
    - Equipment data sheet
    - Equipment specification
    - Equipment requisition
    - Switchgear single line diagram
    - Switchgear typical diagram
    - Architecture drawing
    - Equipment layout drawings
    - Lighting layout drawings
    - Cable routing drawings
    - Cable list
    - Typical installation drawings (power, lighting, earthing, heat tracing)
    - Electrical bulk Material-Take-Off (MTO)
    - Specifications and bill of quantities for construction sub-contracts

- Block diagrams
- Trouble shooting diagrams
- Electrical calculations

- **Instrumentation & Control**
  - Instrumentation & Control Design Specification
  - Specifications for systems (control, ESD, F&G, telecom etc.)
  - System architecture drawing
  - Instrument functional diagram
  - Control narrative
  - Mimic display drawings
  - Safety Integrity Level (SIL) review
  - Instrument list
  - Instrument data sheets
  - Level sketches
  - Main cable routings and Junction Box (JB) location drawing
  - Instrument location & secondary cable routing drawings
  - Cable routing drawings
  - Cable cross section drawings
  - Cable list
  - Instrument bulk material take-off
  - Specifications and bill of quantities for construction sub-contracts
  - Junction box wiring diagram
  - Typical installation drawings
  - Equipment layout drawings
  - Telecommunication equipment layout drawing

- Instrument loop diagram

5.9. Engineering Design Reviews

Engineering design reviews are a key element of baseline centric project execution and are required so that:

- The design accurately addresses project scope
- Critical safety and operating characteristics have been addressed
- The design complies with appropriate revisions of regulatory body and client requirements
- Effectiveness of discipline interfaces are reviewed, and
- Engineering change is identified.

- **Design Reviews:** Design reviews held on the project generally include [Lessard C. Lessard J.,2007]:

  - Process flow diagram reviews
  - General arrangement reviews
  - Plant operations safety reviews, and
  - 3D model reviews.

  The following objective approach should be followed when reviewing the design [Bent J. Thumann A, 1994]:

  - Available input data has been defined and verified
  - Reasonable design paths have been explored
  - Contributory factors have been considered (e.g., operability, reliability, criticality)
  - The design meets the specified requirements
  - Adequate documentation is available to support the design
  - Control measures for residual design/risks have been implemented
  - Design will result in a facility that can be safely installed, inspected, tested, operated,

and maintained to the specified requirements, and

- Capturing key lessons learned from previous projects.

The review leader will ensure checklist items are addressed and completed. The design review checklists may be expanded during the review, as required. During the course of the design review, each attending discipline will ensure that the below items on the design review checklist are fully covered and are included in the overall report to be prepared and issued by the review leader

- Safety/Environmental Reviews
- 3D Model Reviews
- Constructability, Maintainability, Operability
- Technical/Peer Review

5.10. Equipment list and Material management System

An Equipment List is a listing of all tagged equipment with equipment number, service description, capacity, dimension and size, weight, required power, PO number, reference P&ID numbers as well as key summary information of those tagged equipment items.

Material management is an approach for planning, organizing, and controlling all those activities principally concerned with the flow of materials into an organisation.

The general tasks for Material management system applied by lead EPCM companies are as follow [GHD. PPM Sec 12, 2011]:

- **Equipment, Device, and Instrument Numbering:** All equipment shall be assigned a unique identification number as detailed in the company`s relevant procedure. Each portion of the tag number is significant and is developed to facilitate engineering, design, material control, construction, project control, commissioning checkout, operator training and finally, the normal operation of the facilities. All electrical devices and instruments shall be labelled with an appropriate labelling system and equipment tagging where there are control systems and electrical schematics. These tags also are used on the P&ID’s and profile and data sheets.
- **Equipment List and Materials Management:** the equipment list shall be compiled for

mechanical and electrical based on equipment data sheets (EDS) and design drawings. This equipment list is then uploaded to the software once requisitioned for tracking of each piece of equipment from purchase order/contract award to delivery on site and subsequent issue to the contractor.

Equipment List: Equipment lists shall be produced for the SPS, DPS and detailed design phases of the project. The purpose of the equipment list is to:

- Provide a single list of equipment for all stakeholders to use
- Allows appropriate checking by the engineer and client with respect to compliance with agreed rationalized lists and EDS
- Assists MTO to support estimates, and
- Document all equipment to be provided by the engineer and contractors. This list will also be used in compiling construction contracts

Example of equipment which will generally be included in the list is bulk items purchased by client, tagged items purchased by engineer on behalf of client and other items purchased and supplied by the contractors that require monitoring.

Material Management system: specific software is usually used to support the materials management function. This system allows population of all materials/equipment requirements for a project and permits the tracking and management of the materials/equipment from initial identification through to eventual delivery to site and issue to contractors. It shall be populated once procurement activity is commenced via creation and issue of the materials requisition.

6. CONTRACT AND PROCUREMENT MANAGEMENT

6.1. Procurement Management Process

Project procurement management as a coordinated effort with outside suppliers to acquire goods and services for projects. These relationships are made regularly on a contract basis with the goal that the required items or services are received on time and meet the principles required by the procurement company [Guth S,2007].

The provision of goods and services makes up most of the cost of a project. In addition, empirical analysis of past projects revealed that developing unsuitable procurement straggles and contracting models led to significant cost and time overrun. Therefore, developing a fit for purpose contract & procurement strategy for the project is one of the most important strategic management decisions.

Procurement has fundamental principles that are considered by all legislatures in the procurement process. These principles are found in project management companies, utilised in the procurement stages to ensure the following [Watt A,2006]:

- Accountability
- Straightforwardness
- Value for money
- Competition
- Ethics of obtaining products and services

Further indicates procurement management as being one of the most critical areas in project management as it incorporates wide administrative elements of planning, organizing, leading, communicating, staffing and controlling. The importance of building and maintaining healthy relationships between purchasing departments and external suppliers in order to work productively in ordering, receiving, reviewing and approving of all procurement items is essential for project execution [Depaoli, P., Sorrentino, M., & De, M., 2013].

The objectives of applying an appropriate procurement process are: lower costs, management of relationships, reduction of risks, ensuring the security of supply, quality improvements, pursuit of innovation and leveraging technology. The key steps and the associated critical issues in this process are as follows [Baily, Farmer & Jones,2005]:

- **Define Requirements, Identification of work packages and develop sourcing strategy**. This process involves the identification of a work package for a contract or a requisition for equipment or materials by the project team to be tendered in accordance with the package breakdown structure (PBS). The process also involves the development of, or compliance with existing, sourcing plan and supply agreements in place. Purchase requisitions, order forms, and material lists should be accurate and correct as this will ensure that the purchasing department procure the goods or service that will satisfy the identified need of the originator (Puttick & Van Esch, 2003]

- **Prepare Tender/Contract documents**. When specifications are prepared there are many major considerations such as [Dobler & Burnt, 1996]

    - Design considerations of the function
    - Market considerations of consumer acceptance
    - Manufacturing considerations of economical production, and
    - Procurement considerations of markets, materials availability, supplier capabilities, and cost

    It is critical that the tender document is prepared to ensure that the contract scope of work (equipment or material data sheets), relevant specifications, applicable conditions of contract, etc. are correctly and fully defined [Lysons K, 2000]. As the tender documents form the basis of any subsequent contract and/or purchase order and the management thereof, these need to be complete upfront.

    A contract document is prepared to reflect the tender outcome and any negotiations that might have taken place to resolve any differences between the project team's expectations and the vendor's proposal i.e. exclusions, alternative proposals and/or changes to comply with the project scope, cost and schedule requirements.

- **Supplier Engagement including shortlisting of qualified suppliers.** It is essential to an organisation to select the best in class suppliers who are willing to work as partners to continuously strive towards reduced cycle times, quality innovations and cost improvements. The supplier selection process includes prequalification and short listing of qualified suppliers and/or service providers. The subsequent step is the selection of contractors and/or suppliers to be approached for bids.

Normally they are pre-qualified or registered existing vendors who have been assessed to have the necessary capacity and capability to supply the services and/or goods. For some projects, the Client's team may need to seek expression of interest (EOI) process to pre-qualify and short list contractors. In all cases the project team would not ask a vendor to bid if there is any doubt as to their capacity to deliver.

It is also confirmed that improved relationship management between the organisation and the supplier can contribute to improved levels of efficiency for the entire supply chain [Burnett K, 2004].

- **Tender issue, receipt, evaluation, and award.** On receipt of the bids, submitted in accordance with an approved tender procedure, the project team evaluates these both commercially and technically in accordance with a pre-agreed tender evaluation plan. Based on this evaluation, a recommendation is made to award the contract or purchase order and submitted for approval in accordance with the project approval authorities. During the evaluation, it is commonly necessary to request the bidder to clarify their bid either technically and/or commercially.

  The traditional trinity of supplier evaluation and selection criteria namely cost, quality and delivery has evolved into the evaluation of more criteria including: quality, price and cost structure, delivery, time, flexibility, service, financial status and risk management, systems, technology, and supply chain [Hugo et al, 2006].

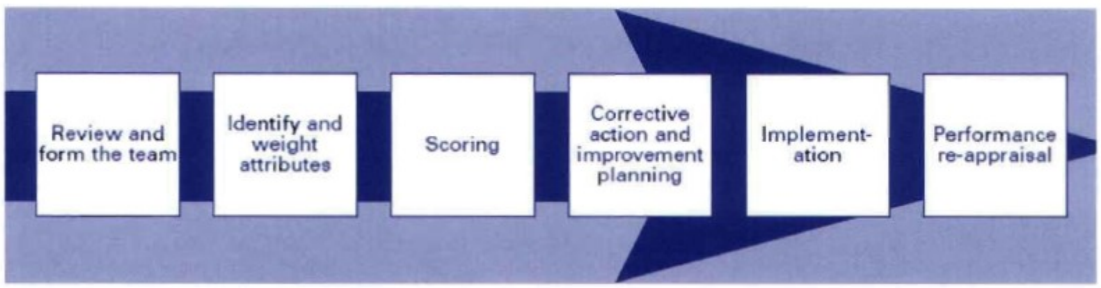
  The selection criteria and the tender adjudication process which consider:

  - Availability and current workload
  - People or project team proposed as most important success factor
  - Organisational capacity and capabilities, relevant experience, and track record
  - Recent project performance in relation to safety, time, cost, quality, stakeholder's management, etc.
  - Integrated systems to handle the data assimilation, analysis, and control requirements of major projects
  - Procedures and processes compliance with legislation, effectiveness, and efficiency drivers.

- Commercial and payment mechanism

- Cost structure and value for money.

The tools and techniques to select, evaluate, and measure suppliers are customized by organisations to ensure that the respective suppliers meet the requirements necessary for the organisation to achieve its business objectives. As an example, a tool called SESPA (Supplier evaluation, selection, and performance appraisal process) will be used to demonstrate the contribution that these tools and techniques can potentially make towards achieving the triple constraint that projects are faced with namely: time, cost, and quality (Appendix 1). The SESPA process can be split into six key sections at Figure 6-1 below [Dreyer J, 2007].



Source: BOC Purchase handbook volume 2 (1998:8)

FIGURE 6-1 **The SESPA process**

- **Contract award and implementation**. Prior to signing the contract the Clients' team/the contract owner ensures compliance with the contract authorization process (e.g. developing and seeking approval on a contract approval request, supplier performance evaluation plan, contract management plan, etc.) Once the contract or purchase order is signed, the contractor proceeds with the execution of the contract in accordance with the agreed scope, specifications, terms and conditions, and schedule. In the case of contracts, the contract is administered and managed. Purchase orders are normally tracked by the inspectors and expeditors to ensure compliance with specifications, the quality management plan, and the delivery schedule.

The procurement department is usually authorised to enter contracts on behalf of the company, and it is usually expected from this department to administer contracts once they are in place [Mochal T, 2006].

On some projects early contractor engagement (ECI) in the study phases is most effective as the contractor can contribute to and share the project vision, scope, and risks. This often results in better alignment between study assumptions, delivery strategy, execution, and constructability

- **Administer Contract, Assess Performance and Manage Changes**. The Client's team/the contract owner ensures the terms and conditions as well as the supplier/contractor's performance continue to meet the business objectives and the agreed performance standard. The Client's team/contract owner also ensures the contract terms and conditions. This includes HSEC, time, cost, quality, and stakeholders' management as well as scope management performance. It is noted that these administrative functions must be conducted in a professional and cost-effective manner [Dobler E., 1990].

Irrespective of which department analyses the invoice, it is important that the invoice is checked against the order to ensure that prices, quantities, and specifications correspond [Puttick & Van E, 2003].

Changes to the scope of work and/or pricing is handled with contract variations as provided for in the contract or purchase order if both parties agree. If the parties do not agree, a claim might arise which needs to be dealt promptly using an agreed procedure [Yogeswaran K. & Kumaraswamy M.M.,1997]. Early identification and accurate recording of events and/or relevant factors are critical to ensure that a claim can be evaluated and decision made whether to settle or reject the claim, in accordance with the project approval framework. Legal advice might be necessary before proceeding. All potential or actual claims are tracked to ensure effective management thereof.

- **Contract close-out**. On completion of the contract and/or purchase order, there must be assurance in place to ensure that the vendor has complied fully with their obligations including acceptance of works, vendor assistance for commissioning and start-up, all vendor documentation, all payments have been finalised, relevant bonds are released, guarantees are in place, transfer of insurable risk identified, etc.

6.2. Contract Strategy

A key component of the procurement strategy is the contracting strategy as to how the contracting-out of specific works, materials, services, and expertise that the client cannot provide for itself, is affected. The contracting strategy addresses both [Murdoch J. Hughes W, 2000]:

- The provision of services (e.g. engineering, procurement, construction, pre-commissioning, logistics, etc.).
- The provision of materials and equipment.

At the latest, the development of the contracting strategy is undertaken early in the definition phase. The contracting strategy is completed and approved as required by project schedule requirements prior to the execution phase.

The overall objective of implementing an appropriate Contracting Strategy for a Project is to increase probability of Project success. The objectives of the Contracting Strategy Best Practice include [COAA, 2018]:

- Contract strategy or strategies developed and implemented are aligned to and supportive of Owner's business and Project objectives
- Key considerations of Project scope, risk, work location conditions are addressed
- The appropriate Project stakeholders are involved in the development, understand and support the Project contract strategy
- Clear and appropriate allocation of Project and contract risk to Contractors and Owners
- Minimize/avoid contract claims and/or disputes
- Clear definition of Project scope roles/responsibilities, communication channels and decision making (this supported by well written, comprehensive contracts and scopes of work aligned to the contract strategy)

The range of contracting options in a project is wide and the option chosen for a package depends on the size and nature of the package and its specific challenges, such as location, risks, complexity, criticality, etc. These options range from traditional to partnership-based contracts and finance schemes (e.g. BOOT schemes) [Rowlinson S. McDermott P, 2005].

As a rule, the project risks and the preferred risk allocation profile determines the most suitable contracting strategy and model for the implementation contractor. The contracting strategy addresses:

- What is to be contracted out and when.
- The project delivery strategy including the preferred packages as well as size and complexity of each package.
- Maturity of scope definition, detail and specificity i.e. engineering progress at time of award.
- The competitive situation, and the capacity and capability of identified vendors.
- The use of horizontal and vertical packages.
- The most suitable types of contracts that addresses the preferred risk allocation profile and the delivery environment.
- A risk analysis of the contracting alternatives for each major package.
- Allocation of risk between client and contractors.
- Industrial relations competencies and current contractor issues.
- Contract schedules including, if appropriate, critical milestones.
- The commercial strategy including:
  - How contractors are remunerated by client.
  - How payment and cost control is established.
  - The proposed use of performance-based incentives to encourage and reward contractors, versus guarantees and penalty regimes to prevent under-performance.
  - How commercial and legal negotiations are handled.
- The type of contracting e.g. tendered or negotiated contract after preliminary proposal(s) or (design) competition.
- Whether special conditions of contract are required in addition to the general conditions of contract.
- Insurance schemes.
- The facilities and services which may be provided by client to contractors.
- The materials or goods which are provided by client to contractors i.e. long lead items supplied by client.

- The minimum requirements for contract monitoring/control.
- Administrative effort and supervision required and availability.

The most used categories of procurement contracts- Explicit Contracting are [Dimitri N. Piga G., 2006]:

- Cost-reimbursement contracts (CRCs)
- Fixed-price contracts (FPC)
- Incentive contracts (ICs)
    - Linear incentive contracts
    - Balancing risk sharing and incentives
    - Incentive contracts and transaction costs
    - Multiple performance dimensions and task heterogeneity
    - Incentive contracts and tendering procedures

Before finalizing the contracting strategy, consideration is given to, but not limited to, the following risks (project execution risks):

- HSEC issues
- Schedule slippage and delays
- Overbudget and cost overrun
- Commercial risks
- Political and economic risks
- Lack of resources and Expertise
- Scope & objective risks, external environment, market considerations, local content, and industrial relations
- Consequence of failure to meet specifications/performance targets
- Industrial relations management issues.

Contract types can be assigned to the project WBS items. The opportunities to group elements of the WBS into logical packages for each work discipline are explored considering the location of work, where the contract type and commercial terms are the same. The result of packaging elements of the WBS into packages is a breakdown of the project scope in terms of technical service agreements, construction contracts, service contracts, purchase orders and internal work orders.

6.3. Procurement Strategy

The empirical analysis of past projects revealed that developing unsuitable procurement straggles and contracting models lead to significant cost and time overrun. Therefore, developing a fit for purpose procurement strategy for the project is one of the most important strategic management decisions. The procurement strategy focuses on the scope of work as well as the goods and services that cannot be supplied by client for reasons such as:

- The work to be performed is not deemed to be part of the client core business.
- The contractor can supply the works, services or goods, procedures, systems, people, and expertise that cannot or cannot sufficiently be made available from the client's own resources.
- The contractor can perform the work at lower cost than client could otherwise perform the work.
- Using a contractor to perform the work reduces the overall risk to client of the work.
- The type, quality, enhancements and fluctuation of required works, services or goods are specific or unique to the contractor's speciality and not client.

The fundamental elements of a procurement strategy incorporating the notion that project delivery and finance are key variables to be managed in the refreshment of the infrastructure portfolio [Miller J.B., 1997c]. These elements are listed below in summary form for discussion and debate [Rowlinson S. McDermott P, 2005]:

- A three-quadrant strategy in which a steadily evolving mix of public and private delivery or finance is the express goal.
- Consideration of alternative project delivery and finance mechanisms as one means for verifying project viability, introducing new technology and generating competition over quality, initial cost, and life cycle cost.

- Comparative discounted cash flow analyses of life-cycle cost in order to permit one to one comparison among the DB, DBB, DBO and BOT contract awards-project scope is clearly defined in advance by the government, either through performance specifications or through design specifications.
- Competition in the award of projects, through well-advertised, well-marketed requests for proposals and invitations to bidders.
- Fair treatment of actual competitors, through even-handed implementation of procurement processes.
- Transparency-signalling fairness to potential competitors through early statement of project and proposal requirements and evaluation criteria.
- An independent engineering check of the efficacy of design to ensure public safety whenever the design function is combined with the construction function.
- Competition which is open to technological change through increased reliance on performance specifications.
- A portfolio approach to optimisation, using discounted cash-flow analyses over the project life cycle as the common denominator to compare alternative configurations of project delivery and finance for a collection of projects [Miller J.B and Evje R.H., 1997]:
- Continuous integration of these concepts into government procurement strategy

The objective of a good procurement strategy is to achieve the best value for money outcomes for client, safeguard the business and project interest by optimising risk allocation, and ensure uninterrupted execution of the project. In preparing the procurement strategy, the project team considers the following:

- Project objectives
- Project Scope of work and the WBS
- The project risk registers
- Market conditions and the supply chain capacity
- Global sourcing strategies

- Strategic supply agreements
- Sole sourcing
- Capacity and capabilities of local contractors and suppliers
- Location specific issues
- Logistics and the importation requirements.
- Purchasing of spares by service provider or Client.
- Code of Business Conduct

6.4. Procurement Procedures

The procurement plan identifies all the key procedures and the development of these procedures for the tender, evaluation, award, administration and close-out of contracts and purchase orders. The procurement procedures address as a minimum, for the Client's team and implementation contractor [Bhp PDM, 2011]:

- Process and workflows.
- Roles and responsibilities
- Project authorities and procurement responsibility matrix
- Strategy for selection of tenderers
- Tender and contract numbering
- Formal process for communication between the project and contractors or suppliers
- Tender period management
- Management of qualifications and exceptions to the standard commercial conditions
- Method of award of commitments
- Expediting and receipt of commercial deliverables, e.g. securities, insurance certificates
- Expediting and receipt of technical deliverables

6.5. Contract and Procurement Plan

It is a requirement that the project execution plan (PEP) provides a high-level summary of the contracts and procurement plan with reference to the detailed plan. The plan defines how the project intends to develop, implement, manage and control all contract and procurement activities needed to deliver the required services, materials and equipment to meet the approved scope of work and in accordance with the approved budget and schedule. All contractual agreements for the project are also executed in accordance with the agreed project authorities as outlined in execution planning and/or the relevant business specific project development and delivery processes and procedures [Lessard C. Lessard J.,2007].

It is good practice to engage the implementation contractor as early as possible in the study phase, the contract for the execution phase only needs to be finalised prior to seeking approval to proceed so that it can be executed on approval. It is further possible to adopt a two stages approach to engaging the implementation contractor. In stage one, the contractor contributes to the project development definition processes and undertakes some FEED work. In stage two, the contractor undertakes the execution phase of the project. Proceeding from stage one to stage two can be conditional on satisfactory performance by the contractor and/or obtaining approval to precede to the execution phase. The two-stage process can be covered by one or two separate contracts.

In any case, in developing the contracts and procurement plan, the project team proceeds through several process steps. Here the project team refers to both the Client's team and the implementation contractor's project team who are jointly responsible for the contracts and procurement plan, although the implementation contractor is primarily responsible for the implementation for their scope of the work. The process steps include the:

- Development of a clearly documented procurement strategy.
- Identification of appropriate contracting strategies for all key work packages.
- Documenting of a detailed procurement process and the associated workflows, which include the approval and governance processes.
- Development of an expediting plan and the associated workflows.
- Development of a complete logistics plan.

- Determination of the insurance requirements for the project.
- Documenting of the process for contract management and administration.
- Design of an appropriate organisation to manage and control all procurement activities.
- Development of the relevant procedures for all procurement activities.
- Documenting of the contracts and procurement plan.

A typical contracts and procurement plan include coverage of topics as summarized in below [Vargas R, 2008]:

- **Project Objectives:** as applicable to procurement
- **Sourcing Strategy:** Outline of the supply market conditions for key goods and services as well as strategy that addresses key market related challenges such as market failure, insufficient competitive tension, quality, availability, budget, transportation, etc.
- **Procurement strategy:** The procurement strategy to supply all equipment, materials and services for the project and the relevant contracting strategy to contract-out the supply thereof.
- **Procurement scope of work:** The procurement requirements and the scope of activities.
- **Specific requirements:** Any specific requirements for contracts and procurement that need to be met or managed during the execution phase including laws, regulations, statutes, and contract terms of conditions.
- **Procurement register:** A detailed procurement register and schedule for all major packages.
- **Progress methodology:** The methodology for measuring and reporting of progress of all procurement activities.
- **Control methodologies:** The management and control methodology for:
    - Selection and approval of contractors and vendors
    - Tendering, evaluation of bids and the award of contracts and purchase orders

- Governance of procurement and contracting processes
- An approval framework
- Quality assurance and quality control including third party inspections and factory acceptance tests
- Expediting and delivery
- Vendor design data and documentation including equipment maintenance and operating manuals
- Materials management
- Contract management and administration
- Vendor assistance
- Close-out

▪ **Procurement organisation structure:** The overall procurement organisation structure including the Client's team organisation, position descriptions, roles and responsibilities for all key procurement management positions and the responsibility matrix for procurement activities and deliverables

▪ **Procedures:** Identification of all procurement procedures and the development thereof

▪ **Risk Management:** A risk assessment is completed for each contract as part of the adjudication process to ensure the right value/risk-based decisions are made. The risks as considered for the contracting strategy are considered for individual contracts.

6.6. Expediting and Delivery Plan:

The process of expediting focuses on the supply of equipment and materials (including offsite fabrication) and starts with award of the contract and/or purchase order until all equipment and materials are onsite in accordance with required onsite (ROS) dates and all vendor documentation being received and approved. Expediting continues until all repairs and/or replacements and spares required in terms of the contract or purchase order are received at site and the supplier's invoice is certified as correct.

The expediting plan is developed as part of the procurement plan and takes into consideration [Bhp PDM, 2011]:

- Market economic conditions
- Shop loading
- Geographical influences
- Shipping impact
- Criticality of equipment and materials including lead times and ROS dates for the construction schedule

To facilitate the preparation of the plan, the following is considered

- Likely location and multi-source potential
- Shop inspections and tests to be carried out
- Inspections or tests are to be witnessed
- Awareness of the importation laws into the host country and the investigation of the best means to reduce or recover taxes and duties
- Appointment of an experienced traffic and logistics group to handle all transport and importation of equipment and material

The project team undertakes the task to plan, schedule and administer all land, sea, freight, insurance, and transport from ex-works to the site. The procurement plan documents the approach to expediting, the resources required and the methodology for the management and control thereof, considering the above.

6.7. Logistics Strategy

Logistics cover the movement of equipment and materials from one location to another, including their packaging, handling, and storage. The timely delivery of equipment and materials in line with required onsite dates and its potential influence on timely project completion is critical to the successful outcome of the project [Lambeck R. Eschemuller J., 2009].

The total logistic cost is very often unknown as the processes involving the transport of equipment and materials can be very fragmented, involving many different parties, with no single point of accountability. A logistics coordination role within the project team from an early stage in the project (latest in the definition phase) to manage the full logistics chain is recognised as best practice, particularly where there is more than one project site and/or a very remote project site. Hence, the need for a logistics plan and the extent thereof varies considerably dependent on the nature and scope of the project, and contracting strategy adopted in the PEP.

It is recommended that at the PEP development stage, a project specific logistics strategy is developed and included. The key elements which are considered in developing this strategy are:

- The location, the local conditions, infrastructure, and its impact on logistics support for the project
- Identifying supply sources and their impact on the supply chain
- Understanding and identifying what must be moved, how and when in terms of weight, volume and any special storage and materials handling requirements including the need and availability of special needs like heavy lift ships
- The consequences of the disposal of surplus material, scrap, waste etc.
- Suitable benchmarks for the performance of the logistics operations in terms of delivery times, cycle times, costs, and safety
- The identification of all options available and consideration of the most effective and efficient ways

Once a logistics strategy has been agreed, a logistics plan is prepared considering the above aspects for inclusion in the procurement plan. The plan considers the above strategic issues as well as:

- The responsibility of the Client, the supplier and/or the contractor for freight movements
- How the logistics aspects are considered at the design and engineering stage
- Planning and timing of more detailed project activities at a later stage and their impact on logistics
- The resourcing of the plan to execute and manage the logistics including mobilisation of specialist contractors

Note that for large and/or remote sites, consideration is also given to the people logistics e.g. accommodation for non-local labour, crew changes, visits to site, bussing of local labour, etc.

6.8. Insurance Strategy

The type and level of insurance coverage required for the project needs to reflect the scope, value and risk profile, the location of work and the jurisdiction of the contract. It is critical that the contract terms and conditions for all agreements are aligned with the insurance strategy [Lambeck R. Eschemuller J., 2009].

Insurance coverage includes, but is not limited to:

- Contract works (for onsite and some offsite locations as required by the project)
- Third party legal liability
- Transit or marine transit insurance, if applicable
- Each contract and purchase order includes conditions of insurance and level of cover required, including but not limited to
- Worker's compensation insurance (where required under the local laws)
- Professional indemnity insurance
- Comprehensive and third-party insurance covering all mechanically propelled vehicles required to be licensed in the state or territory where the work is performed
- Contractors constructional plant including for all property for which the contractor is responsible
- Third party liability for off-site exposure including property of Client in the contractor's care, custody, or control
- Any other insurances which are required by local laws
- Contractors' obligations for insurance, liability for excesses for any claim and the limits to any liability
- Any insurance provided by the Client and the obligations of the contractor in regard to this cover

- Nomination of the Client as the principal and the waiver of subrogation as required for the Client and the contractor/supplier
- The procurement plan documents how the project team gives effect to the above

6.9. Contract Control Procedure

For effective contract control it is essential that:

- A detailed contract management process is developed to support the project contracting and procurement plan
- All formal communication with the contractor be through a dedicated representative of the project team
- The following mechanisms are built into the contract documentation from the tender stage and that these mechanisms are not compromised during contract negotiations:
  - Mechanisms for reporting progress
  - Mechanisms for all payments and retentions and the requirements for performance bonds, guarantees, etc.
  - Mechanisms for agreeing the cost/time consequences of changes
  - Mechanisms for handling claims

The detailed method of control and the requirements for progress reporting vary according to the size and type of contract. All control procedures, however, include within the final contract document:

- Agreed milestone points, including such deliverables (in the form of physical product) as may be appropriate
- Methodology for monitoring and reporting progress
- Coordination and administration procedures with the appropriate rights of access and audit
- Resource schedules (manpower, equipment, services)
- Format and frequency of reports

- Any additional data requirements
- Industrial relations management plans
- Access control
- Mobilisation plan (including any preconditions)
- Quality management plans
- HSEC in design
- Safety management plan including transportation, vetting of equipment brought onto site, etc.
- Change control, variations, and instructions [Marsh P, 2000]
- Payment and claims procedure
- Close-out procedures
- Where appropriate, performance incentives scheme

Contractors are required to impose similar control procedures on their subcontractors and vendors. The project team reserves the right to approve selection of subcontractors or vendors.

In administering the contract, it is important to ensure that weaknesses and/or risks of the contractor, recognised at the tender stage are considered and that the project team's efforts are directed appropriately.

The size and composition of the team managing the contractor is appropriate to the type of contract, capability of the selected contractor and the complexity and importance of the work involved. The authority of the project team representative is established in writing to the contractor. Whilst it is expected that the team managing the contract has the necessary skills to manage claims, in the event of major claims a specialist team is often formed focussing on the resolution of claims and closing out of the contracts. It is good practice to conduct an analysis of causal factors and to identify any lessons learnt, the training and development of project personnel and/or the adjustment of any contract terms and conditions.

6.10. Claim Management Procedure

Project teams are required to develop a legally compliant claims management procedure which includes, but is not limited to [Twort A, 2004]:

- Claims management strategy
- Contract analysis
- Execution analysis, e.g. risks, options, and opportunities
- Supervision and control of work and variations
- Claim identification, including notice requirements
- Quantification of claims, e.g. work completed, quantities, variations, rise and fall, materials on site
- Claims resolution methodology
- Information and record keeping requirements
- Reporting requirements

7. CONSTRUCTION, COMMISSIONING, TRANSITION TO OPERATION MANAGEMENT AND PROJECT CLOSEOUT

7.1. Construction Management

Construction management is a professional service that uses the project management tools and experienced engineers to oversee all aspects of construction works in the project and is one of the last phases in the project's evolution. Construction management is planning, scheduling, evaluation, and controlling of construction tasks and activities to accomplish specific objectives outlined in the contract documents [Charles P.,2012].

Management in the construction industry is a complex task, often complies with regulations and involves with hazardous work. therefore, early involvement of construction expertise in early phases of capital projects is accepted as good practice in delivering a successful project and that produce improvements in safety, schedule, cost, quality and risk management [PMI Construction Extension to the PMBOK® Guide, 2016].

The intent of this chapter is to provide a guidance for a standard approach to develop the core construction planning deliverables in the construction phase. This also covers the components of construction strategy, Construction management plan, construction reviews, commissioning management plan, commissioning strategy, commissioning safety plan, transition to operation, asset management plan & register, operation strategy, operation plan, operational readiness plan, and project close out documents.

Early alignment between operations, construction and commissioning is essential to determine what type, detail and timing of turnover documentation will be at the transitions from construction to pre-commissioning to commissioning to ramp-up and operations.

The construction management functions are typically by a team of construction professionals trained in various aspects of the job. The experienced construction professional will be competent in all of the following management functions [Jackson B., 2010]:

- Estimating the project
- Administrating the contract
- Managing job site and construction operations
- Planning and scheduling the project

- Monitoring project performance
- Managing project quality
- Managing project safety
- Assessing project risks
- Problem solving and decision making

7.1.1 Construction Strategy

A construction management strategy is a coordinated set of decisions which guide a construction project organisation. Construction managers select a range of strategies to enable them to manage individual construction projects. The proactive strategies involve either directly managing the inherent difficulties or altering the factors which cause the inherent difficulty. Managing the inherent difficulty can be achieved by using design build, management contracting or construction management. Altering the factors can be achieved by using partnering or an integrated approach [Radosavljevic M. and Bennett J., 2012].

Delivering the construction phase of a major project requires specialist systems, people and processes that are not generally available internally within the client organisation. It is therefore typical for project teams to engage a specialist implementation contractor to provide this capability. In developing the construction strategy, it is important to initially understand the approach to delivery of the overall project. The construction strategy is therefore developed in conjunction with the execution strategy in addition to the contracting strategy.

The construction strategy covers the aspects as detailed below:

- **Potential construction contractors:**
  - Local and regional contractor experience and recent performance.
  - Construction plant and equipment availability.
  - Level of HSEC awareness and performance in the region.
  - Industrial relations awareness of contractors in region.
  - Systems and procedures i.e. level of maturity.
- **People:**
  - Determining the resources required from scope quantities and productivity

data.

- Availability of resources in the region, country and internationally, taking into account resource demands of other potential projects in the region or country.
- Level of HSEC awareness and performance in the region.
- Industrial relations approach by unions and workforce in region.
- Accommodation: local availability and camp considerations.

▪ **Process:**

- Understanding the site and address site management issues.
- Whether pre-assemblies be used.
- What the transport envelope allows in terms of deliveries and who the key stakeholders to engage at an early stage.
- Whether the stick build sequence will work and fit in with pre-assemblies.
- Whether horizontal or vertical execution scope packages make sense.
- How the workflow will work, from material delivery and storage to the work-fronts on site.

▪ **Key Risks:**

- Identify and assess key construction risks.

7.1.2 Constructability Reviews

Constructability analysis is a process that utilizes experienced construction personnel with extensive construction knowledge early in the design stages of projects to ensure that the projects are buildable, while also being cost effective, biddable, and maintainable [DeWitt S., 1999].

The key purpose of the constructability reviews in the early phase is to define the residual risk ratings of the various alternatives under consideration and to identify whether there are any potential fatal flaws associated with any of the alternatives. This is a fundamental input in the process of evaluating the various alternatives on a risk and value basis.

Constructability has also been defined as ‘the extent to which a design of a facility provides for ease of construction yet meets the overall requirements of the facility’ [Wideman M., 2001]. Continuous constructability studies throughout the planning and design phase can help to anticipate potential problems involving material compatibility, access issues, sequencing problems, dewatering, weather or delivery issues, unnecessary complexity, new or proprietary installation methods and long-term performance. During the planning phase, the constructability reviews are carried out progressively as the scope develops.

To minimise the impact to the cost and schedule and to ensure that the facility functions as intended, the constructability review is considered in these early decisions. Competent, experienced construction professionals work in conjunction with the project team to plan the project execution and select the best alternatives for the design and construction of the project.

Once the initial constructability reviews are completed for all facilities, the construction manager coordinates a suitably facilitated constructability value improving practice workshop which includes participation of key Client's representatives from production, engineering, procurement, HSE and construction. This serves to enhance the value improvement to be gained from the final round of detailed constructability reviews which follow completion of the initial reviews and which considers the latest scope definition as developed in parallel by engineering.

Both constructability analysis and value engineering practices focus on quality and costs. Constructability emphasis more on safety and scheduling, and constructability tends to involve collaboration of designers and constructors from the outset of the project life cycle [Dorsey R.W, 1997].

The constructability reviews consider the following as a minimum:

- Project constraints such as security, weather, remote location, culture, labour availability
- Construction sequence
- Construction methodology
- Site access issues
- Commissioning sequence requirements
- The environment for competing projects that may draw on contracting capability

Once the constructability reviews are suitably developed to allow engineering to progress, the next step is to develop the construction management plan.

7.1.3 Construction Management Plan

The construction management plan (CMP) outlines the approach to construction, sets boundary limits and details key activities that need to be completed by the construction management team to successfully establish the construction function and complete the construction scope. The construction management plan aims to complete a project in the safest, most efficient and timely manner. Ensuring cooperative efforts of designers and construction contractors during the definition phase reduces problems encountered during construction.

The construction management plan includes any reporting requirements associated with safety, schedule, contractor interface, operations planning and cost management. The construction management plan is a key deliverable of the definition phase as part of the overall PEP. It forms the contract between the project leader and the construction management team as they are ultimately a service provider to the project and commissioning managers.

The intent of the construction management plan is to provide guidance for a standard approach to manage a construction site and set the expectations of how the execution phase of a project is delivered. It covers the agreed scope, responsibilities, and procedures for all the construction functions, including the construction services and site administration.

A typical construction management plan includes coverage of topics as summarised below. This is used as a guide as the extent of information required within a plan is determined by the scope and complexity of the project [CMAA Construction Management Standards of Practice, 2010].

- **Introduction:** This section states the purpose, objectives, foundation, and an overview of the project.

  Battery Limits: The construction management plan identifies any project scope items managed outside the construction management plan. Management of the interfaces are subject to intensive control and risk review, particular in safety.

  Construction Execution Methodology: The construction methodology sets the strategy that the construction management plan is based on, covering construction approach, planning, and scheduling, contracting strategy for subcontractor management, etc.

- **Construction team and organization:** The capacity and capability of the construction team engaged on the project plays a significant role in determining the extent to which the project objectives are met or exceeded.

- **Contractor pre-qualification:** The construction management plan clearly outlines the requirements that need to be met prior to selection and mobilisation of site contractors.
- **Construction temporary facilities:** This section details what facilities are required on site for the execution phase (e.g. security office, construction office facilities) for client, the implementation contractor and construction contractor teams.
- **HSEC:** The information contained within this section complies with standard procedures and policies, relevant legislation and fully details how all site construction activities are managed.
- **Mobilization and De-mobilization:** The section includes all details as to how and who is responsible for mobilisation and demobilisation of the construction team and also considers how the construction contractor(s) are managed during these phases.
- **Employee and industrial relations**: Often this information is guided by corporate policies, but each project may introduce a different philosophy or strategy for how it is managed.
- **Field Engineering requirements:** This is an area that is normally overlooked or not given the level of effort it deserves. If a project is well-defined and the definition phase has been carried out with sufficient detail, the site engineering support may be reduced.
- **Quality management:** The objective is to establish an effective quality management system for the project and define how quality is implemented and maintained for the entire construction execution phase and handover to the commissioning team.
- **Preservation of equipment:** The construction management plan considers the requirement to preserve materials and equipment prior to handover.
    - **Tie-ins and interconnections:** Tie-ins management is a critical part of many projects. As tie-ins typically involve interference with a current operation, they require attention in terms of isolation procedures, systems, processes and communication to ensure minimal interruption to plant operation.
- **Procedures:** This section identifies the procedures that are applied on the project during the construction stage of the execution phase.

- **Site administration and contracts management:** This section covers how the construction site is managed. It covers roster cycles, security, construction facilities and how they are managed.

- **Field project controls:** The construction management plan outlines the requirements for field cost and schedule control.

- **Procurement:** This is a critical part of the execution methodology that needs to clearly state if client`s procurement system is used for order placement (equipment, materials, contracts), contract payment etc., or whether the implementation contractor assumes the responsibility using their own procurement system. In part, this may dictate the contracting strategy for the execution phase.

- **Materials Management:** This section aligns with the procurement strategy as to how equipment and materials are managed and whether they are free issued or are purchased by the implementation contractor or construction contractor(s).

- **Construction Risks:** The construction team identifies, assesses, and mitigates construction risks. Clear responsibility is assigned between the Client's team, implementation contractor and construction contractors. The effectiveness of the implementation of mitigations is checked and controlled on an ongoing basis.

- **Construction verification:** Construction verification includes the inspection of completed construction work and the collection of all information and preparation of necessary documentation, including as-built drawings, for each project facility, structure and operating system required to establish conformance with contract requirements and industry standards.

- **Construction Closeout:** This section is the final deliverable for the construction stage of the execution phase. The construction management plan describes the required content of the construction closeout report.

7.2. Commissioning Management

Commissioning is a series of project activities planned and executed to bring the newly constructed facilities, equipment and/or systems into operation through the system users [Institution of Civil Engineers 1996]. The commissioning activities of any project mark the transition from the execution phase to the operation phase. It is critical that these activities are logical, structured and executed based on plans pre-agreed between the project and (asset owner's) operations teams. Concerning to the Commissioning objectives, it will provide a fully functional facility:

- Whose systems, equipment and components have been proven to meet all Client's functional requirements before the date of acceptance and operate consistently at peak efficiencies and within specified energy budgets under all normal loads.
- In which the Client and Operations and Maintenance personnel will have been fully trained in all aspects of all installed systems,
- Having optimized life cycle costs,
- Having complete documentation relating to all installed equipment and systems

The desired and optimal sequence for plant commissioning is ideally the foundation on which the overall project schedule has been built. The project construction schedule is built back from the most desirable plant start up sequence. This is set early in the project life when the project schedule is being developed in the definition phase. The ideal or natural plant start-up sequence is established by the Client's and/or operations team and in contingent on the complexity of the project. Services supply, support infrastructure and the control system normally require commissioning and establishment ahead of any individual plant area.

Typically, the plant is broken down into a hierarchy. Different terminology is sometimes used but commonly the breakdown starts with facilities, which are logical sections of a plant or sub processes of the overall process. Facilities are then divided into logical systems and then into sub-systems.

A sub-system is comprised of items of equipment, piping, structures, and electrical components. It is the least number of integrated equipment and components that can be controlled independently and forms the basic building block for pre-commissioning and commissioning.

Several or more sub-systems combine to form a system which is the unit on which the commissioning sequence and plant start-up can be planned. Systems then combine to form the plant facility.

Plant hierarchy and the number of divisions is dependent on the particular project, but it is important that the sub-division and accompanying commissioning sequence is established early by the project team and aligned to construction. The hierarchy and the agreed target commissioning sequence are included in the commissioning plan document.

Below is the list of deliverables relating to the commissioning process [PSPC Canada, 2018]:

- **Construction Verification**: That is a milestone where construction is complete and installation of equipment, piping, electrical services, instrumentation/controls, and utilities has physically been completed & validated in accordance with the detail design & contract requirements, but not energized. Upon completion of this activity, the project team issues a `Notice of Energisation (NOE)` authorising the start of pre-commissioning.

- **Pre-commissioning or Dry Commissioning:** this process involves the various work activities and specific testing necessary to ensure individual subsystems or systems are operable, safe to operate and ready for full dynamic testing and commissioning process. These functions are carried out and documented through the discipline-specific checks. At the completion of pre-commissioning, a certificate of `Mechanical completion` as well as `A ready-for-commissioning certificate` are issued.

  Pre-commissioning consists of two key steps, namely: - Checking and Testing of individual equipment and - Testing and operating the equipment grouped together into modules or systems, but without product.

  The Pre-commissioning includes the deliverables such as:

  - **In-plant performance operational verification tests and results.**
  - **Pre-start-up tests:** such as pressure, static, flushing, cleaning, "bumping", etc. conducted during construction and will be performed by the Contractor.
  - **Pre-start-up inspections**: conducted by the Designer prior to start-up and rectification of deficiencies, using approved installation check lists.
  - **Start-up**: This will be by the Contractor, equipment manufacturer, supplier and/or installing specialist sub-contractor under the direction of the Designer.
  - **Performance verification**: will be performed by the approved Commissioning Agencies, repeated where necessary until results are acceptable to the Designer.
  - **A punch list**: Itemising and listing of equipment, construction or installation deficiencies and is an important component of progressing through the stages of commissioning. Punch lists are used as a tool to achieve safe, tested and contractually complete facilities prior to handing over equipment and process circuits for pre-commissioning at the end of construction. They are similarly employed at the end of pre-commissioning when handing over sub-systems and systems at practical completion ready for commissioning and load testing.

- **Commissioning of Integrated Systems, WET Commissioning or Hand Over**: The purpose of this stage is to test the operability of the entirety of system from automatic sequence, functionality, whole of system's view point and make sure the integrated system is ready for ramp-up . The intent is to demonstrate a level of capability and reliability consistent with project design and process specifications and meet agreed operational criteria suitable for final handover and acceptance. Upon completion of commissioning, certification is issued to demonstrate that the system is `ready for ramp-up`. The following list provides an overview of commissioning deliverables:
    - Pre-ramp-up safety review.
    - Commissioning function tests, results, and documentation
    - Complete check sheets, commissioning procedures and punch list items
    - Complete system turnover and completion package
    - A completed punch lists
- **Performance Verification or Ramp-up**: This process is the beginning of the production and increasing production to the project design. This is point where the execution phase will end and full transition to the operation phase will occur. In many instances, the operations team requires a series of pre-determined performance tests be completed to verify that the facilities or systems are performing as specified at steady state operating conditions. The performance criteria, method of assessment and the way the facilities/equipment or systems are to be fully handed over to operations are agreed prior to commencement of final testing.

  Ramp-up includes the introduction of process fluids into systems whereby all equipment and processes are placed into continuous operation after final testing is performed. The following list provides an overview of Ramp-up deliverables:
    - **An Identification System**: will be established for all systems and equipment which will reflect final MMS (Maintenance Management System) identification requirements and will be used in the Asset register.
    - **Commissioning specifications**: will be developed and submitted at the same time as the Design Development Report.
    - **Installation Start-up Check Lists:** A generic list is provided to inform the

Commissioning Manager of those systems which are ready for commissioning.

- **Product Information (PI) report:** All product information relating to equipment and components supplied and installed on this project will be reported on the approved PI report like the samples attached to the commissioning specifications.

- **Performance verification (PV) and testing** involves operating the facility and carrying out a series of defined tasks, demonstrations, and tests to measure the new plant and equipment against the contract, design and nameplate parameters.

- **Commissioning Reports:** The completed PV report forms will be included in properly formatted Commissioning Reports.

- **Tasks for the Warranty Period:** While all commissioning activities must be completed before the issuance of the Interim Certificate, it is anticipated that certain commissioning activities will be necessary during the warranty period reflected in contract agreement.

- **Handover documentation:** The commissioning team together with the construction and operations teams clearly identifies the handover documentation required between each stage of commissioning and formulate process for the formal handover thereof and the issue of appropriate certificates.

7.2.1 Commissioning Strategy

As the project transitions through the approval process, a commissioning strategy is developed as an input to the PEP. This strategy defines the overall approach as to how the project team will commission all newly constructed facilities, systems and equipment to bring them into operation in a safe, controlled and sustainable way and describes the management structure required to meet the overall project objectives. It identifies the key technical expertise required to execute the commissioning activities, how they are sourced, and it defines the quality control process.

In developing the strategy, alignment of the construction milestones with the commissioning milestones in line with the commissioning sequence is required to assure completion of the overall project plan. Early involvement of experienced commissioning personnel in the preparation of commissioning plans is essential. The strategy recognises the value of operational staff on the commissioning team and provides for their participation.

7.2.2 Commissioning Management Plan

The commissioning plan is a project specific document that outlines the scope and defines the responsibilities, process, schedules, and documentation requirements of the commissioning process. A preliminary commissioning management plan is outlined during the definition phase of the project however the detailed and developed plan is formed at early execution phase. It should [Deramchi S. and Hawkins G., 2009]:

- Provide general information about the project and strategies
- Identify the commissioning team members during each stage of commissioning process. It is critical that the commissioning manager is involved in the very early design phases
- Define the roles and responsibilities for each commissioning team member.
- Identify the scope and systems to be commissioned
- Create a schedule of the commissioning activities for each stage of both pre-commissioning & commissioning process. This will cover commissioning sequences
- Establish documentation requirements associated with the commissioning process
- Establish communication and reporting procedures for the commissioning process
- Establish sufficient budget and resources for the development and implementation of the various handover packages
- Outline a clear handover plan and other required procedures
- Identify Test Requirements**:** an outline of full test list, team, required special tools, and testing milestones
- Define HSEC plan addressing key risks and mitigation strategies and Risk Management Plan
- Define Success factors: A list of measurable key success factors for the commissioning activities
- Documentation

- Outline Specialist Contractor Plan: A list of and schedule for required outside expertise with a contracting strategy and contractor management plan
- Define Punch list process and written procedures for equipment isolations, equipment tagging, and work permits
- Identify Training program: An integrated training program coordinated with the operations team to assure key skills are addressed
- Outline QA/QC process, and Change management plan suitable for the commissioning activity

The Commissioning Management Plan will be reviewed, revised, refined, and updated as detailed design and production of the Working Documents proceeds and, if required, during construction. Each time it is revised, the revision number and date will also be revised. The revised Commissioning Plan shall be submitted to the client for review and approval.

7.2.3 Commissioning Safety Plan

The Planning phase is where safety should be reviewed before the commissioning is essential. A thorough understanding of the project scope during the planning phase is required to develop the schedule for the various system and equipment commissioning. The schedule can be part of the commissioning safety plan, which will address various coordination requirements, such as the impact of systems becoming energized at various points during the commissioning timeline. This could potentially necessitate a change in procedures including safe plan of action forms or restricting personnel access in a rolling manner. Following items shall be considered in developing commissioning safety plan [DPS Group Global, 2018]:

- Required safety training for the staff
- An assessment of any procedural differences to verify which procedures will be followed and how they need to be documented
- “lessons learned” into the front-end planning of the commissioning efforts and review any concerns from similar past projects
- Location and accessibility review of the isolation and shut-off mechanisms to ensure the required safety procedures can be executed

- Hazards and risks identification with a mitigation plan for the systems particularly for the commissioning and start-up of the newly completed facilities and equipment
- Defined roles and responsibilities
- A commissioning work plan developed to provide appropriate safety training, reduce unsafe conditions, and minimise work interferences
- A summary of safety protocols for controlling plant and equipment
- A full list of accepted standards and vendors safety strategy with training materials

7.3. Transition to Operations

Client usually plan to establish an operations team at the appropriate stage of a project's development. This team is responsible for supporting the project during commissioning and takes responsibility for the plant on handover to operations. It is important to carefully align the operations personnel with the project teams and particularly with the technology providers. The commissioning process provides a unique training opportunity for the operations team.

The transition to operations is sometimes referred to as the handover of project ownership. It refers to a formal transfer of responsibility, care, custody and control of the facilities and equipment from the project team to the operations team. The transition to operations comprises of two key stages.

- **Commissioning to operations:** The commissioning team verifies that all required and agreed documentation has been progressively handed over prior to operations accepting transfer of ownership. Facilities are generally handed over from the commissioning team to the operations team as and when they are commissioned.
- **Operational Readiness:** The operations readiness and hand-over plan provides outline of the operations strategy and operations plan as well as a clear guideline for the safe and effective transition to the operation phase during and post commissioning.

7.3.1 Asset Register

A good asset management can help in several ways to manage large expenditure and for this an asset register is vital. An asset register is essentially a list of an organisation's assets and their condition and helps an organisation to ascertain what it owns or leases, the stock of that item, find out where that asset resides and who is responsible for it. The asset register can feed into an asset management system which contains information about the asset's maintenance schedule. The organisation can plan for replacements more concisely, and it is a record for insurance claims and auditors.

The financial management related assets typically fall into three classes: property, fixed assets and removable assets. The asset register should typically only include details of the last two categories as property assets are likely to be kept in a separate register. An asset register can contain information including [SWG, 2019]:

- An asset's ID number
- Make
- Model and description
- Location
- Warranty details
- Lease end date or disposal details where applicable
- Expected lifespan
- Purchase price and indirect costs (freight, installation etc,)

Data input into the register is done either by the Client's team or the implementation contractor, as nominated in the contract or agreed between the parties. Where appropriate, details on items supplied by the Client are provided by the Client's team to the implementation contractor for completeness of the asset register.

7.3.2 Operations Readiness Plan

Operations readiness involves a multi-disciplined approach to ensure all aspects required to operate an asset are in place. Operations readiness describes the process by which an operational team prepares for full time and sustained operation of an asset or processing facility following handover from a project team. For this to occur and be considered successful, several systems need to be in place. These systems can be broadly categorised into the following areas: Organisation, HSEC, Human resources, Risk/change management, Financial management, Asset management, and Facilities. A comprehensive operational readiness plan covers the followings [Emerson R.C., 2018]:

- Operations and Maintenance Philosophies and Strategies
- HSE Readiness
- Maintenance and Reliability Readiness
- Technical Integrity Readiness
- Operations Readiness
- IT systems and Master Data Readiness
- Supply Chain Readiness
- Maintenance and Reliability Management Systems
- Operations and Maintenance Organizational Readiness
- Operations and Maintenance Infrastructure Readiness
- Asset Operations and Maintenance Management
- Asset Commissioning
- Operational Sustainability: Ensuring there are strategies for operating and maintaining plant and equipment integrity through the application of continuous improvement techniques

7.3.3 Operations Strategy

Operations strategy is the total pattern of decisions which shape the long-term capabilities of an operation and their contribution to overall strategy. It is also defined Operations strategy is the total pattern of decisions which shape the long-term capabilities of any type of operation and their contribution to overall strategy. The completed strategy document is a key foundation document for the preparation of the operations readiness and handover plan. This strategy document states the critical operational assumptions agreed as part of the project development, including [Slack N. and Lewis M., 2002]:

- Configuring operations capacity
- Capacity Dynamics
- Supply Network Relationships
- Supply Network Behaviour
- Process Definition- Characteristics and Definition
- Process Technology- Choice and Implementation
- Operations Organisation and Role
- Operations Development and Improvement
- Product and service development and organisation

In addition, empirical analysis of past projects performance revealed that early engagement and integration of the operations team in the project team is a key success factor for major projects.

7.3.4 Operations Plan

Operations management is concerned with managing the resources that directly produce the organization's service or product. The resources will usually consist of people, materials, technology, and information but may go wider than this. These resources are brought together by a series of processes so that they are utilized to deliver the primary service or product of the organization. Thus, operations are concerned with managing inputs (resources) through transformation processes to deliver outputs (service or products) [Rowbotham F. and Galloway L., 2007].

The operations plan describes how the project equipment and facilities are operated and maintained during the life of operation. The plan provides the necessary framework for ensuring that the operations organisation has the tools required and is sufficiently prepared, skilled, and resourced to support and maintain the asset on an ongoing basis. It includes the documentation of the following items:

- Operations strategy
- Operations HSEC plan
- Operations Risk plan
- Operations OBS
- Operations Supply Strategy
- Operations Maintenance strategy
- Operations Staffing plan, Training requirements, and roles & responsibilities
- Operations management process
- Operations financial management plan
- Work Permit Procedures
- Engineering Drawing revision control, queries procedure, and Operations Change management process
- And all simultaneous operations procedures

7.3.5 Training Plan

In the project, the commissioning schedule will indicate in detail how training will be implemented and the duration of each training session. The typical components of the Training plan are as follows [PSPC Canada, 2018]:

- General
- The Development deadline of the Training Plan
- Responsibilities
- Instructors
- Trainees
- Prerequisite skills and qualifications

- Details of Training
- Training Materials
- Videotaping
- Standards of Training
- Limitations
- Demonstrations
- Manufacturers' video-based training

7.4. Project Close- out

The process of closing out a project is recognised as one of the core work process groups associated with the life cycle of the project. The key objective of the close-out process is to ensure that [Lessard C. Lessard J.,2007]:

- All project related agreements and contracts are closed
- Completion of all project activities is documented
- The project outcomes and actual performance are documented
- All relevant project documentation is handed over and/or archived
- Lessons learnt are identified and documented

According to the [Heerkens G, 2002], key deliverables of the project close out can be classified to the documents below:

- Project close out plan
- Project completion report
- IPA close out evaluation
- Benchmarking workbooks
- Project close out report- PCOR

In the large projects, a specialist team is often engaged to assure that project closeout is carried out in the best manner possible. All tasks in this phase can be divided into two categories [Bennett F.L, 2003]:

1- **Completing the work**, which includes the physical activities that must be accomplished on the site. Completion the work consists of the followings:

   a. **Testing and Start Up:** Depending on the nature of the project, there may be substantial amounts of testing and initial start-up of various systems, especially mechanical and electrical systems. The installer of each system will have made them operational, but the specifications will usually require that they be started and tested under operational conditions at the end of the project. In any cases, Proper records of the test will include the date and location, the persons involved, the methods and the results [Mincks W.R. and Johnston H., 1998].

   b. **Clean-up**: it includes the removal of various temporary facilities such as haul roads, security fencing, utilities, storage sheds and offices, as well as surplus materials, scrap, and construction plant. Disturbed landscaping, walkways and drainage facilities may need to be put back to their original condition and any off-site streets used by the those working on the project may need to be repaired and cleaned

   c. **Preliminary punch lists**: or an inspection list, refers to a list of work items yet to be completed, including repairs and discrepancies, to fulfil the contract's requirements. Punch lists are prepared in various forms, but all contain the location of the needed work, its description, and the party responsible for the correction, with some means to indicate when the item has been remedied.

   d. **Pre-final inspection**: This is a major event in the project's life! Representatives from all the design disciplines, the client's organisation, and all major subcontractors as well as the prime contractor participate in this inspection, which is in the charge of the client and its representatives. For a large project, a thorough tour and inspection are made of all of the project's features and systems. Some of the testing and start-up activities may take place as well.

   e. **Final Punch list**: It contains those items still requiring effort in order for the project to be accepted. Whereas there may be several preliminary punch lists, perhaps one for each subcontractor, the usual practice is to prepare a single final punch list for the contractor, who will then coordinate with the various parties to assure compliance. If some items are still defective, the punch list must be revised.

f. **Final Inspection**: When the contractor believes that all punch list items have been taken care of, the client is notified that the project is ready for its final inspection. It involves ascertaining only whether those items on the final punch list have been corrected. Depending on the outcome of this inspection, the client and its design professional will declare the project to be either complete or substantially complete and will issue an appropriate certificate.

g. **Beneficial occupancy**: In any case, the project comes to the point where it can be used for its intended purpose, whether it is fully complete. At this point, beneficial occupancy is said to have begun. The issuance of a certificate of completion or substantial completion marks the beginning of this period. The beginning of beneficial occupancy has at least two important legal implications. First, from that point forward, the project is considered contractually 'complete' and liquidated damages, if any, cannot be assessed for the time after that date. Second, the time for any warranties and guarantees provided by the contractor begins at that time. The client of the completed project can, at this point, begin to move in and occupy the property, to 'benefit from its occupancy' [Bennett F.L, 2003].

h. **Keys**: A special concern on building projects is the handling of keys. As the project is being built and doors are installed, the contractor needs some means of locking most doors. Upon completion, the client will insist that new locks and keys be installed, just prior to beneficial occupancy. When it is time for the client to occupy the building, these locks are replaced with the permanent keying system.

i. **Personnel Actions**: it involves moving team to the other projects or terminating the employment of the field and office personnel if their services are no longer required.

j. **Closing the construction office and Demobilization:** Along with the office, any construction plant remaining on the site must be removed unless client possess those.

2- **Closing out the project**, involving the multitude of required documents and other paperwork issues, some related obviously to finances but others to certificates, project records and provision to the client of the required training, operational information, spare parts and the like. Closing out the project consists of the followings:

  a. **Subcontractor payment:** One of the things the contractor must do before it can receive its final payment, including any retainage that has been withheld, is to complete paying its subcontractors. Thus, as the project nears completion, the contractor must work with each subcontractor to determine the amount of work remaining and its value, the approximate completion dates for the remaining work, the amount of payment due, including any retainage amounts withheld by the contractor and any disputed claims or payments [Mincks W.R. and Johnston H., 1998]. As noted above, remaining work is identified formally on the subcontractor's punch list.

  b. **Final release or waiver of liens:** A lien is a claim against property that can be filed by material suppliers, subcontractors, individuals and, in some cases, design professionals, that helps to assure that the filer of the lien will be paid.

  c. **Consent of surety:** On projects that require a payment bond from the contractor, the client normally requires a consent of surety for final payment prior to making final payment to the contractor. This completed form is issued by the bonding company and assures the client that the surety company approves of the payment to the contractor. The surety can audit the contractor's records to verify that no unexpected financial obligations exist prior to issuing the release. Since the payment bond guarantees that the contractor will pay its obligations, a client, making final payment before the surety has given consent, could be placed in a vulnerable position if the contractor fails to pay its workers, material suppliers or subcontractors [Fisk E.R., 2003].

  d. **Final quantities:** The type of contract determines whether the contractor and client must monitor and agree upon quantities placed into the project. Under a lump-sum/fixed-price contract, the contractor will be paid its contract price adjusted for variations (change orders) regardless of the actual quantities used. If the contract is of the cost-plus type, the contractor must provide documentation for its actual reimbursable costs, as provided in the contract. In the case of a unit-price/measure-and value contract, the parties must measure the quantities actually put in place, for periodic payments throughout the project and for the final payment [Bennett F.L, 2003].

e. **Request for final payment:** The contractor's final payment is equal to the total contract price minus the total of all previous periodic payments made by the client. The form of the request is, therefore, like that used for all the previous partial payment requests. However, as discussed in previous sections, for final payment the contractor must comply with several special stipulations and provide evidence with its payment request. The work covered by the request for final payment will include any work resulting from variations (change orders). Claims and disputes ought to be resolved by the time of this request, if they are not, the request must contain a statement that it is presented subject to the resolution of these matters [Bennett F.L, 2003].

f. **Liquidated damages:** Once the beneficial occupancy date has been established, the parties can determine whether liquidated damages are to be assessed against the contractor, by comparing that date with the completion date established in the original contract or by any extensions thereto. The amount of these damages, to be assessed by reducing the final payment, is calculated simply as the product of the daily liquidated damages amount stated in the contract and the number of days late. If the contract provides for a bonus for early completion, that amount will be calculated in the same manner and will be added to the final payment. In some contracts, liquidated damages are assessed against portions of the work and bonus payments may be figured in the same way. The New Zealand Conditions of Contract for Building and Civil Engineering Construction [Standards New Zealand Paerewa Aotearoa, 1998] include an important provision regarding liquidated damages: 'Payment or deduction of liquidated damages for late completion shall not relieve the Contractor from any of its other liabilities or obligations under the contract.

g. **Final payment and release of retainage:** If all punch list items have been completed, all certificates, affidavits and other documents submitted and in good order and all other obligations completed, the contractor's request for final payment ought, finally, to be honoured. Included with this payment should be the retainage that has been held by the client pending satisfactory completion.

h. Final accounting and cost control completion: The contractor's organisation ought to have a standard form on which summaries of project costs are reported, so that executive management personnel can make valid comparisons with similar previous projects and use the experience to make informed decisions about future projects.

i. Certificates: at close out phase of the project following certificates can be issued

i. Certificate for payment

ii. Contractor's certificate of completion

iii. Certificate of substantial completion

iv. Certificate of completion

v. Certificate of occupancy

j. As-built drawings: Most contracts require that the contractor maintain a set of record drawings, commonly known as as-builts, as the project progresses. On these documents are recorded actual locations, dimensions and features that are different from the original contract drawings.

k. Operating and maintenance manuals: A typical contract provision requires that the contractor furnish operating and maintenance manuals for all the project's equipment and operating systems. The main effort involves simply gathering and organising the documents as they are received from the manufacturers.

l. Records archiving and transfer: Project records are essential parts of the project's history and are also important in the operation and maintenance of the finished work. The availability of project websites and computer-based document management systems allows the archiving of these materials electronically. Such information will be useful for the planning of future projects and for providing data if questions or legal proceedings arise about the project just concluded.

m. Training sessions: Yet another obligation sometimes required of the contractor is to conduct training sessions for the client's operating personnel. Thus, it is the contractor's responsibility to arrange such sessions, probably led by manufacturers' and/or subcontractors' representatives, after the various components are installed and prior to client occupancy.

n. Warranties, guarantees and defects liability period: The terms warranty and guarantee tend to be used interchangeably in construction contracts to designate the obligations the contractor assumes for repairing defects in its work for a specified period after the commencement of beneficial occupancy. The general conditions cover the overall obligation and the time period, called the defects liability period or the maintenance period.

o. **Post-project analysis, critique, and report:** Internally, the contractor will want to analyse the entire project to determine what it has learnt that can be applied to the next such endeavour. This step is probably one of the most neglected aspects of construction project management, as there is always pressured to look ahead to the next job rather than backward toward the work just complete.

p. Client feedback: Many clients provide their contractors and design professionals with their own project performance evaluations. If they do not, the contractor would do well to seek such feedback from the Client.

q. **A closing comment:** it should be noted that completion and hand over of the project asset register represents a record of the fixed assets delivered by the project from financial accounting, taxation, and custodial perspective. Therefore, close out and hand over documentation reflect, and meet the asset capitalisation requirements.

8. SCHEDULE DEVELOPMENT PRACTICE

One of the most significant project management deliverables in the planning phase of construction projects is the integrated project schedule. The value of the accurate and reliable project schedule in the large and complex Engineering, Procurement, and construction management projects is always outmost. This formal deliverable is normally part of contract documents and can be used as a basis of conducting team performance analysis including subcontractors & suppliers, project performance calculations, delay analysis, extension of time, claim management, cost estimates, project cash flows, project funds requirement, and procurement management plan.

In many construction projects, insufficient works on the schedule components and lack of schedule auditing process lead to increase consequent changes, risks, errors, claims, reworks, low morale, and low satisfactions of clients.

The proposed project was initiated to establish and deliver an ore car repair shop and supporting infrastructure in the North of Western Australia. This project is selected in our case study due to the followings:

- Its uniqueness in terms of using the new technology
- First project was built in rail industry in the world
- Has an application to construct the similar project in the other developing countries
- Covers typical engineering, construction, commissioning, and ramp up process/activities applicable almost in all EPC or EPCM type of contracts
- Has variety of the contract and procurement strategies described in this chapter
- Has its own complexity on managing the sole contractors, international suppliers, and third parties
- A clear construction method in a time and cost-effective manner reflected in the schedule sequence
- A clear project scope definition, WBS, boundaries, interface milestones, exclusions, coding structures, production rates, and constraints defined in this

chapter

- A comprehensive project estimates (materials, equipment, manpower, and required budgets) have been linked to the project schedule
- The concept, content, and framework of the conducted schedule analysis are applicable to almost all construction projects
- The regular Schedule Risk workshops are performed and the outcome for identified risks are implemented in the project schedule. The result of schedule risk analysis is explained in this chapter
- Project was successfully completed within the contractual time frame, approved budget, and defined qualities

This project was proposed to be constructed in logical and sequential stages to align with business capacity growth and other key business constraints. The design requirements of the project shall ensure the facility can be expanded in a cost effective manner whilst minimising the effect on production of operations as well as meeting the organisation's key safety objective i.e. Zero Harm.

The project shall be delivered within approved budget, schedule, and quality.

The project is delivered in two stages i.e.:

- Workshop and supporting infrastructure
- Maintenance process equipment

The client intends to award the EPCM contract for the execution phase to a single organisation. The EPCM project team shall deliver the NPI and PE components of the project.

8.1. Scope of Work

This section contains a summary of the NPI and PE scope of work to be implemented at the project precinct (Figure 8-1).

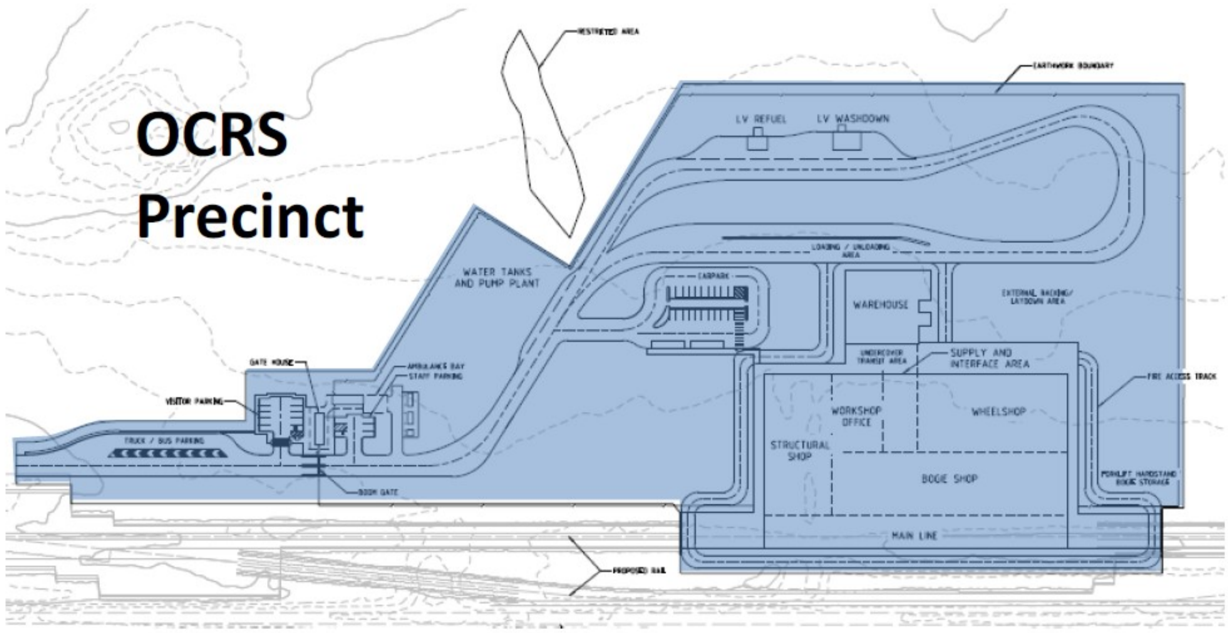


Figure 8-1 Project Precinct

The project scope consists of a workshop and associated support facilities housing a range of ore car repair workstations and equipment.

Non-Process infrastructure (NPI)

NPI is comprised of:

- **Workshop and Admin Office**: the ore car will be transported into the workshop by automated guided vehicles (AGVs). AGVs will also be the primary means of transport for various components of the ore car through the various workstations. The workshop has included a communications room to house communications and automation process control equipment. A double story admin office is included within the workshop. The workshop office can accommodate future expansion with maximum day time staff and includes workstations, quiet rooms, a training room, crib, store, communication rooms, ablution facilities, lockers, etc.
- **Warehouse:** the repair/maintenance functions of the workshop will be supported by the warehouse located next to workshop which will receive, store, and issue the parts and consumables necessary for operations of ore car repair shop workshop. The material interface area will manage the transition of materials between the warehouse (forklifts) and workshop (AGVs).
- **Warehouse storage yard:** external storage yard is located adjacent to the warehouse

building to store bulky items such as wheelsets, wheels, bogies, brake assemblies.

- **Gate House:** the gate house will provide the single security control point for project precinct. The gate house will receive screen, check in/out counter and induct visitors to the workshop. The scope also included adjacent parking, monitoring facilities, communications, kitchen, and ablution facilities. A second transportable building in gate house precinct will provide first aid, drug and alcohol testing facilities.
- **LV Fuelling Facility:** provides refuelling of onsite light vehicles only.
- **LV wash down Facility:** designed for cleaning of on-site vehicles, light commercial vehicles and forklifts.
- **Portable Water Reticulation**: is distributed throughout the workshop for drinking water, ablutions, safety showers etc.
- **Raw/Fire water storage and distribution:** non-potable water will be sourced from the potable water system and shall be stored in a combination raw water/fire water reserve tank at the water supply compound. Subsequently raw water/ fire water will be distributed throughout the site for hydrants, fire sprinklers, hose reels and the LV wash down facility as appropriate.
- **Transfer Pump station:** sewage generated at the site will be gravity fed to a pump station and pumped to the project staging facilities.
- **Oily Water treatment plant:** the oily water generated from waste sources such as light vehicles refuelling facility and LV wash down facility is locally collected and then treated on site in a modular oily water treatment plant. The treated effluent will be monitored for hydrocarbon levels and once compliant the effluent will be discharged to transfer pump station.
- **Site wide Earthworks and drainage:** includes workshop finish floor level, pads, roads servicing the workshop, a hard-stand area and precinct facilities. Site drainage is provided mainly open drains, with provision of culverts under roads.
- **Site Wide Services:** communication systems and services includes fibre optic backbone, fixed voice and data communications via, Telstra, free-to-air television services in crib room, video conferencing system, CCTV system, security access control system, intercom system, analogue addressable fire detection system, and mobile voice radio communications. Services will be reticulated around the site in combined trenches to safely provide adequate levels of services to the facilities.
- **Electrical Services:** High voltage: includes main transformer, HV ring main, and

three transformers serving Gatehouse, Warehouse, and workshop.

- **Electrical Services: Low voltage:** each kiosk substation has associated power distribution panel from which the power is reticulated via underground conduits and pits to various equipment distribution boards.

Process Equipment (PE)

The process equipment includes all fixed and mobile equipment, procedures, process, automation, systems, and tools. The five key equipment areas are outlined below:

- **Main Line:** the main tasks of main line are as follows:
  - Uncouple brake hoses and hand brake chains
  - Remove and replace bogies/wheelsets
  - Inspection of ore car body
  - Remove and replace couplers
  - Remove and replace knuckles
  - Change brake valves
  - Change hand brakes
  - Number and identification tag replacement
  - Change hoses bags and cocks
  - Couple ore car brake hoses and hand brake chains
  - Brake test
- **Bogie Shop:** the main tasks to be undertaken in the bogie shop are as follows:
  - Brake cylinder leak test
  - Inspect/ replace side bearer blocks
  - Inspection, removal, and replacement as required of bogie brake components
  - Adjustment of bogies frame
  - Removal of wheelsets from bogies
  - Disassembly and assembly of bogie frames

- **Wheel Shop:** the main tasks to be undertaken in the wheel shop are as follows:
  - Wheelset qualifying
  - Bearing and end cap removal and re-assembling
  - Wheelset re-profiling
  - Wheelset remanufacturing
- **Structural Shop**: the structural repair is undertaken off-line in the structural repair area. The structural shop will have various material handling aids to assist operators with routine tasks.
- **Material interface station and parts distribution**: this area is responsible for timely transport of correct components, consumables and waste between warehouse and stations within the process equipment. Material interface will be carried out by automated guided vehicles or manually operated shuttle.
- **Automated Guided Vehicles (AGVs):** AGVs are the primary method of transport for ore cars, their components, and other supplies throughout the ore car repair shop. The paths associated with the AGVs provide links between stations and to the materials interface station. AGVs utilise mobile frames to allow them to transport and deliver ore car bodies or bogies to stations to be picked up once required tasks have been completed. Three different type types of AGV`s are required for operations:
  - Ore car body AGV
  - Bogie AGV
  - Distribution AGV
- **Control System**
- **Main PLC**
- **AGV Control system**
- **Wheel shop Control System**
- **HMI System**
- **Cardax System**
- **Rolling Stock Reliability System (RSRS)**

8.2. Project Implementation Basis

The schedule is based on the project being delivered by a single EPCM. The EPCM is responsible for engaging contractors and specialist process equipment suppliers. During execution, the project will be managed through two distinct phases:

- The NPI contractor will manage and control site during NPI construction and PE installation
- EPCM will control and manage commissioning phase

8.3. Contracting Strategy

The contracting strategy is as follows:

- The NPI scope will be executed as a competitively bid "Design and Construct" contract which will also include responsibility for PE installation. The contractor will be selected based on their capabilities, availabilities, competitive pricing, and previous project performance.
- The process equipment scope (excluding portal lathes) will be contracted under a competitively bid integrated PE manufacture and supply package that includes:
    - Design and manufacture
    - Delivered duty paid to site
    - Site commissioning and testing will be contracted directly with the PE contractor
- The portal lathes be ordered separately as a design, manufacture, and supply contract. The installation of which, will be responsibility of the NPI contractor but commissioned by PE contractor.

Below is the summary of contracting strategy and work packages (Table 8-1):

Table 8-1 Project Contract Strategy

Scope	Contract		
	NPI (Building, Facilities and PE Installation)	**PL** (Portal Lathes)	**PE** (Process Equipment)
NPI			
Design	√		
Supply	√		
Install	√		
Commission	√		
PL			
Design		√	
Supply		√	
Unload and Unpack	√	Supervise	
Install	√	Supervise	Supervise
Commission		Supervise	√
PE			
Design			√
Supply			√
Unload and Unpack	√		Supervise
Install	√		Supervise
Commission		Supervise	√

8.4. Implementation Strategy

Contracts and Procurement Packages

Three major and five minor contracts will be used to deliver the NPI and process equipment scope. The major package includes portal lathes, process equipment, and buildings and facilities.

The process equipment, buildings and facilities contracts will be design and manufacture/construct type contracts. The packages are illustrated in Table 8-2.

Table 8-2 Contract & Procurement Packages

Contract & Procurement			
Category	Package No.	Work Group	Package Description
PE	Contract Pack 01	Manufacture & Supply	Portal Lathes
	Contract Pack 02	Manufacture & Supply	Process Equipment including: Wheel Shope, Bogie Shope, Structural Shop, Mainline, AGVs, and Control System
NPI	Contract Pack 03	Construction	Buildings & Facilities

Portal lathes and the portal lathe long lead sub-components packages will be contracted prior to the client board approving the project. Pre-commitment funding has been approved for this purpose and this removes the portal lathe work package supply from the critical path. Client operations have ordered an exact portal lathe from a sole supplier. The contracting cycle reflects a sole source strategy where the equipment specification is already well understood by the contractor.

The process equipment and building & facilities packages will both the tendered prior to the qualified contractors.

Manufacture and Delivery

Whilst the contracting strategy is for the PE to be supplied under a single contract package, the schedule has been broken down to show several sub-packages for the manufacture and delivery phase. The packages have been selected to group together the equipment into packages of similar types of equipment with common design and manufacture periods.

The durations are based on the design produced during definition phase study and formal feedback received from industry via request for quotation process.

The portal lathes are shown as separate package as only one lathe can be manufactured, and factory acceptance tested at a time.

The PE package and all its components are scheduled to commence simultaneously with delivery to site of the whole package at once. An assessment of the available laydown space at site to receive and store PE in its original packing has been undertaken. There is sufficient laydown area and appropriate equipment assumed to be on site to handle the volume of equipment arriving simultaneously. This approach to scheduling of the PE is considered conservative and will allow the PE contractor sufficient time to sub-contract packages.

The portal lathe contractor will design and manufacture the portal lathes. Following factory acceptance testing the lathes will be shipped then transported to site. The portal lathe contractor will supervise the unpacking and installation of portal lathes.

The PE contractor will design, manufacture and procure the process equipment. Following factory acceptance testing the process equipment will be shipped and subsequently then transported to site. The PE contractor will supervise the unloading and installation of the PE.

Construction and Installation

NPI

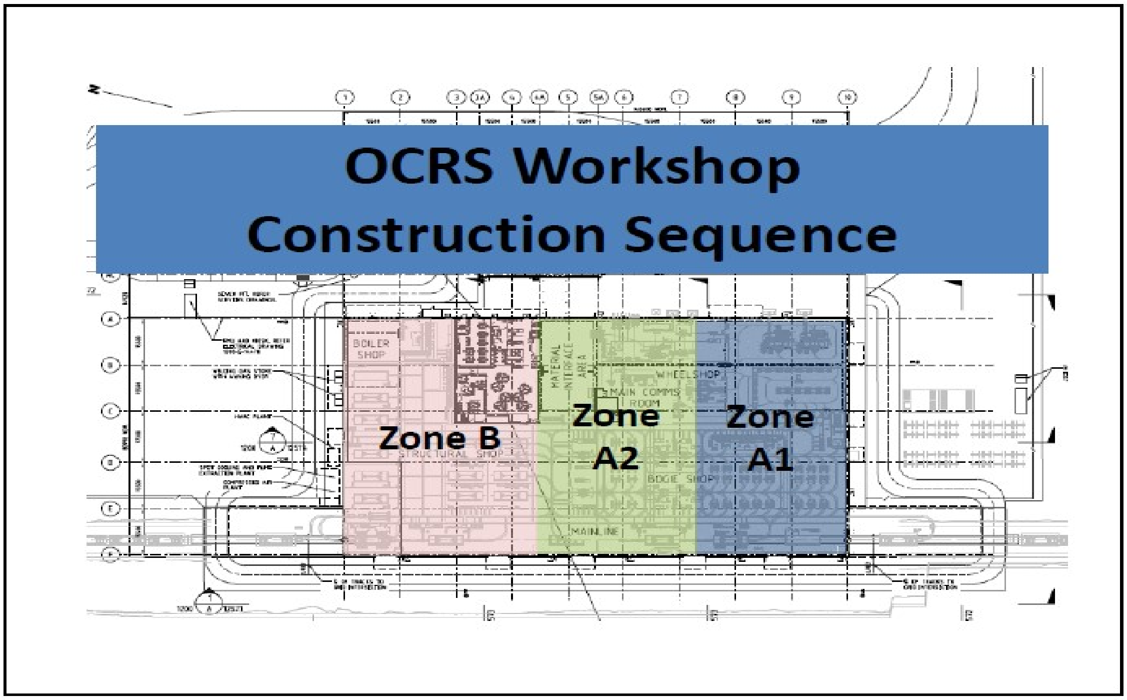
Following award, the NPI contractor will plan the pre-construction activities and establish a home office design and construction team. Upon approval to mobilise to site, the contractor will commence site establishment and early works.

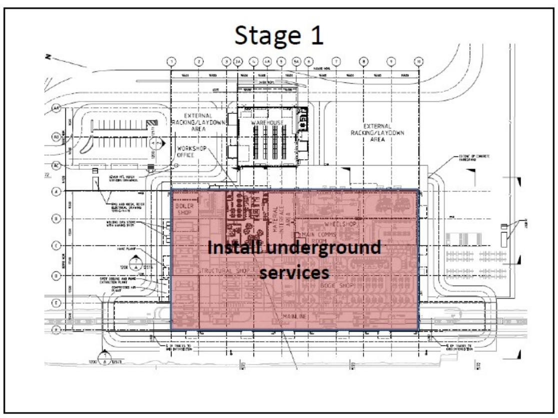
Once design of the underground services has been approved the NPI contractor will construct the underground services, commencing with activities required to be completed to align with completion of the workshop.

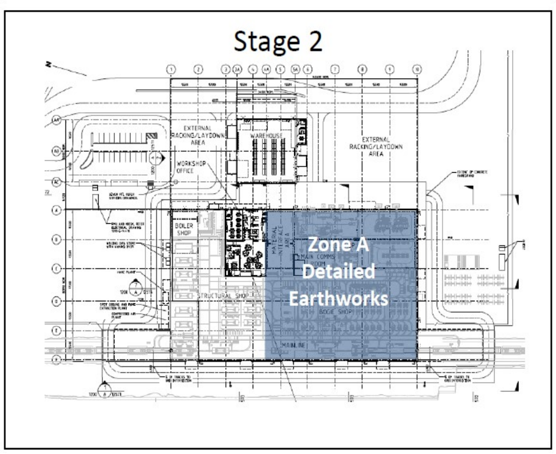
The plan for construction of the workshop building was broken into three zones (A1, A2 and B) with zone containing the portal lathes (A1) to be completed first. This approach was taken to ensure that the portal lathes are kept off the critical plan. A milestone payment in the NPI contract will be utilised to ensure the portal lathes are installed in a timely manner.

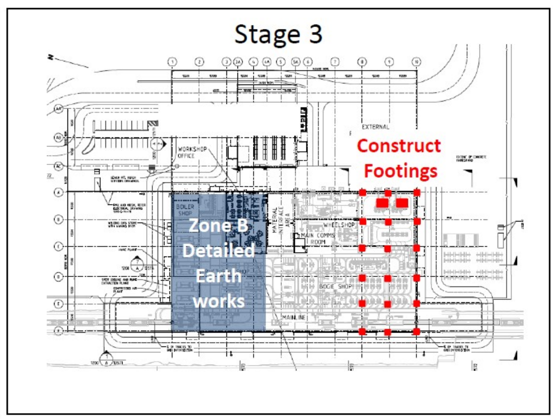
Once the underground services for the workshop zone A1 and A2 and design of the workshop is completed, the detailed earthworks for the workshop commence.

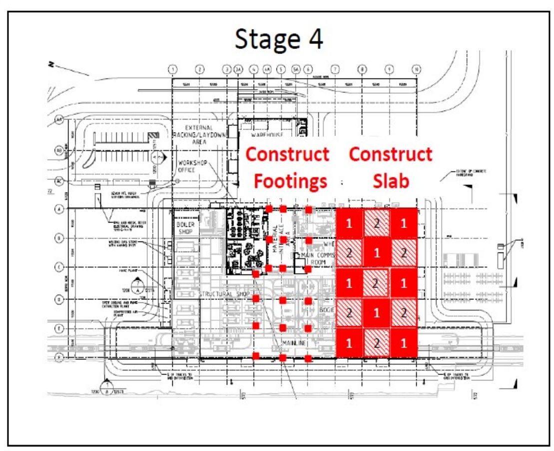
Once the detailed earthworks are completed for zone A1 and A2, the detailed earthworks for zone B and foundation works for zone A1 can commence. A series of sketches showing the construction sequences of the workshop is as per the below 11 stages illustrated in Figure 8-2.


OCRS Workshop
Construction Sequence
Zone B
Zone A2
Zone A1


Stage 1
Install underground services


Stage 2
Zone A Detailed Earthworks


Stage 3
Construct Footings
Zone B Detailed Earth works


Stage 4
Construct Footings
Construct Slab

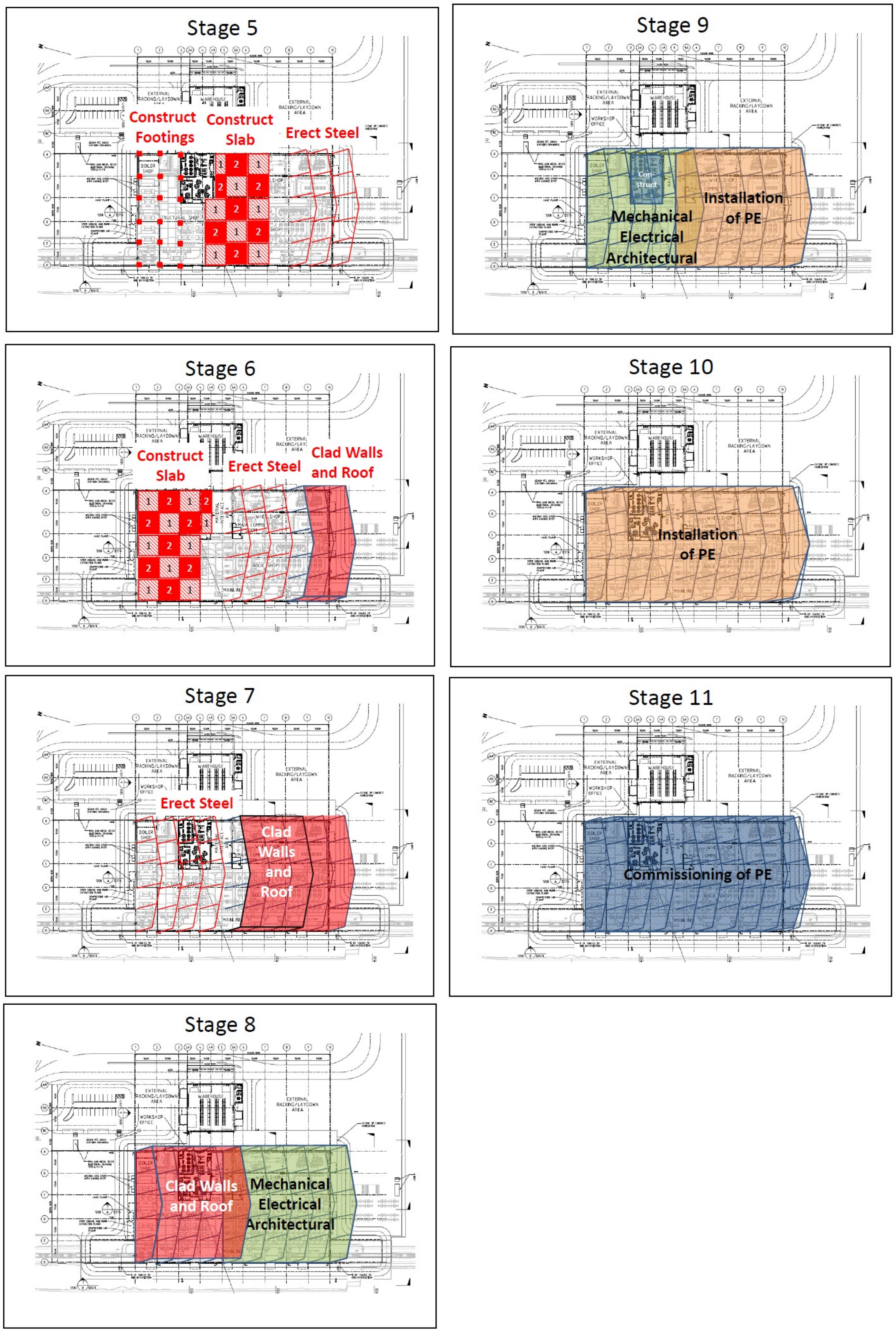


FIGURE 8-2 Construction Sequence

Once this package of work is completed in the workshop that team will be moved onto the warehouse and other facilities on the site.

Once zone A1 and A2 are commissioned the installation of process equipment commences. This is to ensure a clear work area is provided for the installation resources and the workshop power distribution and gantry cranes can be used.

Process Equipment

The durations for installation of the PE are based on formal feedback received from industry during the quotation process.

The manning profiles for the process equipment installation are consistent with expected crew sizes. An assessment of the access and logistics for the installation of the equipment was undertaken and no significant issues were identified.

The contracts and procurement strategy which includes the PE installation in the NPI construction scope of work mitigates some of the risks associated with concurrently undertaking process equipment installation and NPI construction work.

Once all of process equipment is installed the commissioning of PE commences.

Commissioning and Handover

Commissioning and handover will be implemented, managed, and controlled in accordance with EPCM commissioning management plan. The plan will follow client handover and acceptance procedure.

NPI

Following completion of construction of zones of the workshop the NPI equipment and facilities will be commissioned to enable the facilities to be used for the installation and commissioning of PE.

The overhead gantry crane above the portal lathes has been assumed to be usable for installation of portal lathes. Therefore, the commissioning of Zone A and gantry crane is to be completed prior to commencement of installation of the PE. The first item to PE to be installed shall be portal lathe 1.

The warehouse, gatehouse, LV washes, refuel facilities and utility services will be completed and commissioned progressively. The completion, commissioning and handover of these facilities do not drive the critical path, however all NPI facilities need to be commissioned prior the completion of the PE installation.

PE

Commissioning the portal lathes and PE will be managed by the PE contractor and EPCM. The portal lathe contractor will be in attendance to supervise the commissioning.

The commissioning of the PE has been scheduled on the basis that all the PE must be installed before commissioning commences.

The physical size and special layout of the PE will enable commissioning to be carried out on multiple fronts simultaneously. The portal lathes can be being commissioned at the same time as AGV`s are being commissioned on the mainline.

The commissioning sequence of the PE will be in the order of sub-systems, systems, areas, and whole ore car repair shop system. The PE commissioning plan will require close coordination with client operations to ensure the client operators are on-hand to participate in commissioning process. Several systems will require client operations personnel to physically operate the equipment to ensure acceptable system operability.

Ramp up

The ramp-up period is scheduled for a period of 12 weeks. The PE and portal lathe contractor will be required to conduct training on site to the client operation personnel.

8.5. Schedule Work Breakdown Structure

Based on the project SOW, the EPCM schedule for NPI and PE is based on the following WBS structure shown at Tables 8-3, 8-4 and 8-5.

➢ **Engineering**

TABLE 8-3 WBS- Engineering

Level 1	Level 2	Level 3
Engineering	DPS Phase	-
	Engineering for D&C Tender (IFT)	Portal Lathes
		Process Equipment
		NPI Works

➢ **Contract and Procurement**

TABLE 8-4 WBS- Contract & Procurement

Level 1	Level 2
Contracts & Procurement	Portal Lathes
	Process Equipment
	NPI Works

➢ **Off-site Fabrication**

TABLE 8-5 WBS- Fabrication

Level 1	Level 2	Level 3
Fabrication & Delivery	Portal Lathes	First Lathe
		Second Lathe
	Process Equipment	Wheel Shop
		AGV`s
		Bogie Shop
		Main Line
		Structural Shop
		Control System

➢ **Construction and Installation**

Site activities are split up between NPI and PE at level 2 and then at discipline level within the physical location:

Table 8-6 Construction and Installation

Level 3	Level 4	Level 5
Site Establishment & Enabling Works	-	-
D&C Contractor's Detailed Engineering	-	-
Fabrication of Steel	-	-
Main Workshop and other Non Process Infrastructure	Sitewide Underground	-
	OCRS Main Workshop	Detailed Earthworks
		Foundations
		Ground Slab
		Steel Structure
		Roofing & Cladding
		Mechanical Works
		Electrical Works
		Architectural Works
	Other Buildings, Facilities and Finishing Works	Transformer Kiosks
		Warehouse
		Gate House
		LV Refuel Facility
		Light Vehicle Washdown Facility
		Oily Water Treatment Plant &
		Potable/Raw/Fire Water Facility
		Roads , Drains , Car Parks and

- **<u>Commissioning</u>**

Table 8-7 Commissioning

Level 3	Level 4	Level 5
Main Workshop and other Non Process Infrastructure	OCRS Main Workshop	-
	Other Buildings, Facilities and Finishing Works	Warehouse
		Gate House
		LV Refuel Facility
		Light Vehicle Washdown Facility
		Oily Water Treatment Plant &
		Potable/Raw/Fire Water Facility
		Roads , Drains , Car Parks and Finishing Works
Process Equipment	-	-

- **<u>Operations Ramp up</u>**

8.6. Schedule Calendars

A series of global calendars shall be implemented across the program to suit the various activities and phases of work:

Following base assumptions are applied in the scheduling process:

- **Engineering Calendar:** 5 days per week calendar, 8 working hours per day for engineering and office-based resources with provision for public holidays and Christmas.
- **Contract and Procurement Calendar:** 5 days per week calendar, 8 working hours per day for procurement and contracts with provision for public holidays and Christmas.
- **Fabrication and Delivery Calendar:** 7 days per week calendar, 8 working hours per day of fabrication with no provision of public holidays and Christmas.
- **Construction and Installation Calendar:** 6 days per week calendar, 8 working hours per day for construction and installation activities with provision for public holidays and Christmas. Exception: 5 days per week calendar, 8 working hours per day for first quarter of each year.
- **Commissioning Calendar:** 7 days per week calendar, 8 working hours per day for commissioning activities with provision of 14 days Christmas holidays only.
- **Ramp up Calendar:** 7 days per week calendar, 8 working hours per day for operation ramp up activities with provision of 14 days Christmas holidays only.

8.7. Project Quantities

Material take-offs are prepared by the engineering team and quantity surveyor on an area and commodity basis. The MTO`s are neat quantities as defined by models, drawings, and calculations.

Where possible, quantities of the estimate scope are provided in sufficient detail to allow unit pricing to be applied to arrive at a total estimated value. Quantities are expressed in units of measure in accordance with the client procedure.

The NPI scope is defined in a series of work packs carried out by the EPCM. Engineering calculations are completed, and drawings prepared to detail the design requirements and to form the basis of engineering quantity development.

The PE scope is developed based on layouts, equipment lists, process tables, timing charts and process flow charts. To ensure the PE systems meet the required performance with regards to throughput, a dynamic model was developed. The dynamic model was used to verify that the selected equipment would be capable of achieving throughput performance.

Project major quantities are categorised by following commodities:

- Earthworks and Civils- M3
- Concrete- M3
- Steel Structure- Ton
- Architectural- M2
- Mechanical- Each
- Piping- ML
- Electrical- ML
- Control Systems- Each

Below table is the summary of overall project quantity estimates:

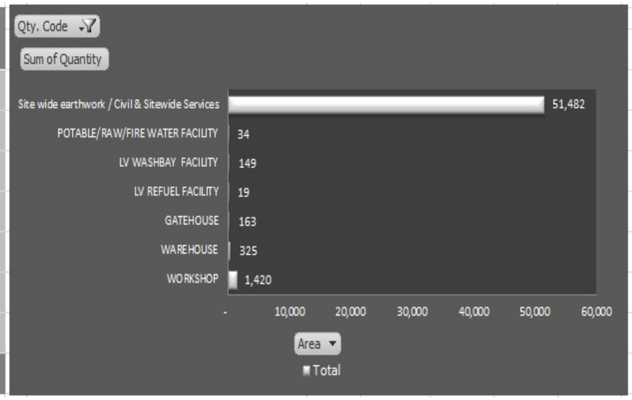
Table 8-8 Project Quantity Estimates- Summary

Discipline Description	UOM	WORKSHOP	WORKSHOP OFFICE	WAREHOUSE	GATEHOUSE	LV REFUEL FACILITY	LV WASHBAY FACILITY	OILY WATER TREATMENT	POTABLE/RAW/FIRE WATER FACILITY	Site wide earthwork / Civil & Sitewide Services	OVERALL CONTROL SYSTEM	Grand Total
Detail Earthworks/Civils	M3	1420		325	163	19	149		34	51482		53,592
Concrete	M3	4712	6	547	43	34	43		15			5,400
Steelwork	TONNE	660	64	90	2	7	5		2			830
Architectural	M2	10396	1576	2404	100	100	177					14,754
Mechanical	EACH	116	47		8	7	5					183
Piping	M	3525	191	30	70	100	102		126	1435		5,579
Electrical	M	51857	5904	1500	200	1000	750	250	250	6149		67,860
Control Systems	EACH	477	280	104		7	2	21	16	57	130	1,094

➤ <u>Earthwork quantity- M3</u>

TABLE 8-9 Earthwork Quantity- M3

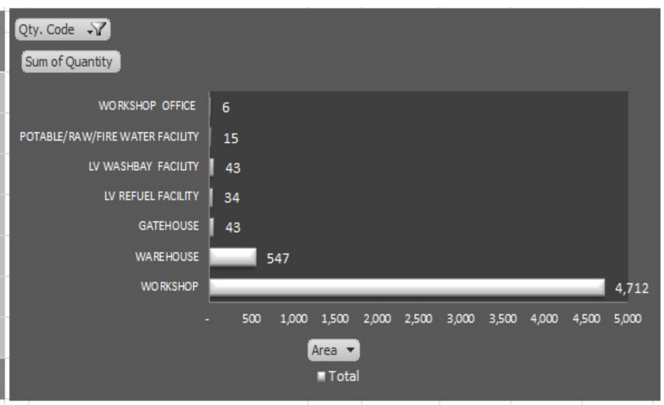
Area	Total
GATEHOUSE	163
LV REFUEL FACILITY	19
LV WASHBAY FACILITY	149
POTABLE/RAW/FIRE WATER FACILITY	34
Site wide earthwork / Civil & Sitewide Services	51,482
WAREHOUSE	325
WORKSHOP	1,420
Grand Total	53,592



➤ <u>Concrete quantity- M3</u>

TABLE 8-10 Concrete Quantity- M3

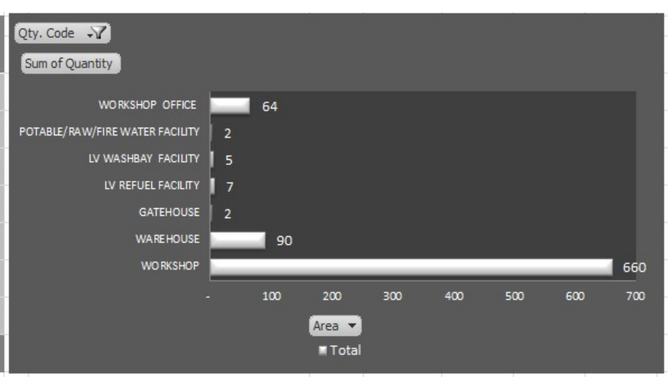
Area	Total
GATEHOUSE	43
LV REFUEL FACILITY	34
LV WASHBAY FACILITY	43
POTABLE/RAW/FIRE WATER FACILITY	15
WAREHOUSE	547
WORKSHOP	4,712
WORKSHOP OFFICE	6
Grand Total	5,400



➤ Steel quantity- Tonnage

Table 8-11 Steel Structure Quantity- Tons

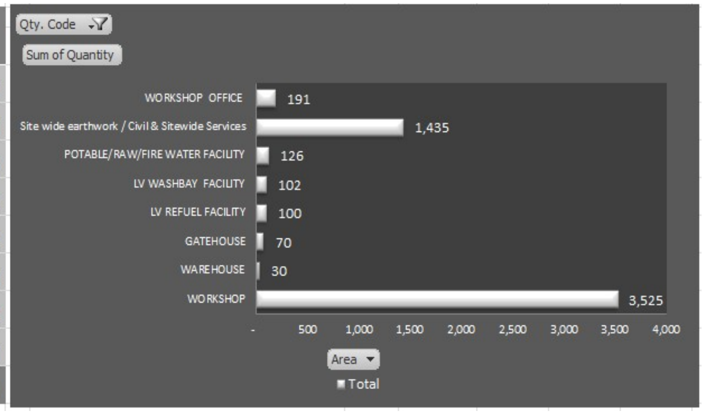
Area	Total
GATEHOUSE	2
LV REFUEL FACILITY	7
LV WASHBAY FACILITY	5
POTABLE/RAW/FIRE WATER FACILITY	2
WAREHOUSE	90
WORKSHOP	660
WORKSHOP OFFICE	64
Grand Total	830



➢ **Piping quantity**

TABLE 8-12 Piping Quantity- LM

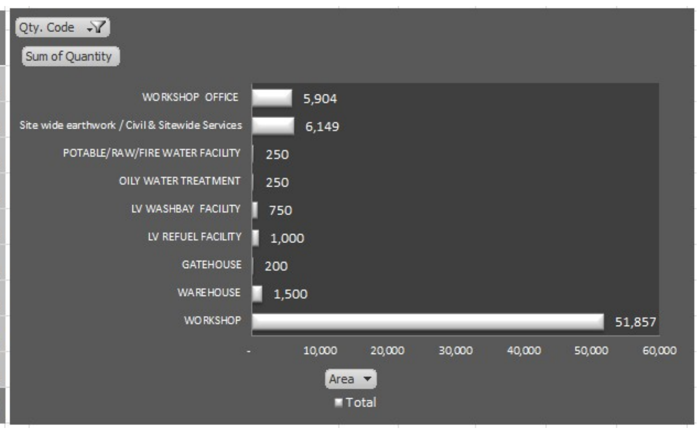
Area	Total
GATEHOUSE	70
LV REFUEL FACILITY	100
LV WASHBAY FACILITY	102
POTABLE/RAW/FIRE WATER FACILITY	126
Site wide earthwork / Civil & Sitewide Services	1,435
WAREHOUSE	30
WORKSHOP	3,525
WORKSHOP OFFICE	191
Grand Total	**5,579**



➢ **Electrical quantity**

TABLE 8-13 Electrical Quantity- LM

Area	Total
GATEHOUSE	200
LV REFUEL FACILITY	1,000
LV WASHBAY FACILITY	750
OILY WATER TREATMENT	250
POTABLE/RAW/FIRE WATER FACILITY	250
Site wide earthwork / Civil & Sitewide Services	6,149
WAREHOUSE	1,500
WORKSHOP	51,857
WORKSHOP OFFICE	5,904
Grand Total	**67,860**



8.8. Project Direct Man-Hours estimates

Direct man-hours are estimated from the engineered scope and quantities taken off from drawings as well as industry standards.

NPI installation & commissioning hours are estimated on a crew or task basis. This estimating technique involved estimating the number of craftsmen that are required to perform a specific task and the time to perform the task. The resulting man-hours are included in the project estimates.

PE installation & commissioning hours: the requests for quotation for the process equipment packages also asked the supplier to provide estimates for the installation labour required to install their equipment.

NPI construction labour hours are estimated as per quantities with a provision for project efficiency factor (productivity factor: PF)

Exclusions:

- EPCM services estimates
- Hours associated with Client
- Heritage clearance
- Government consultation and approvals
- Negotiations for environmental management plan
- Permits and licence fees
- Operating hours to run the facilities after hand over
- Indirect hours

Below is the summary of direct hours estimate by area/discipline that shall be loaded in the EPCM schedule:

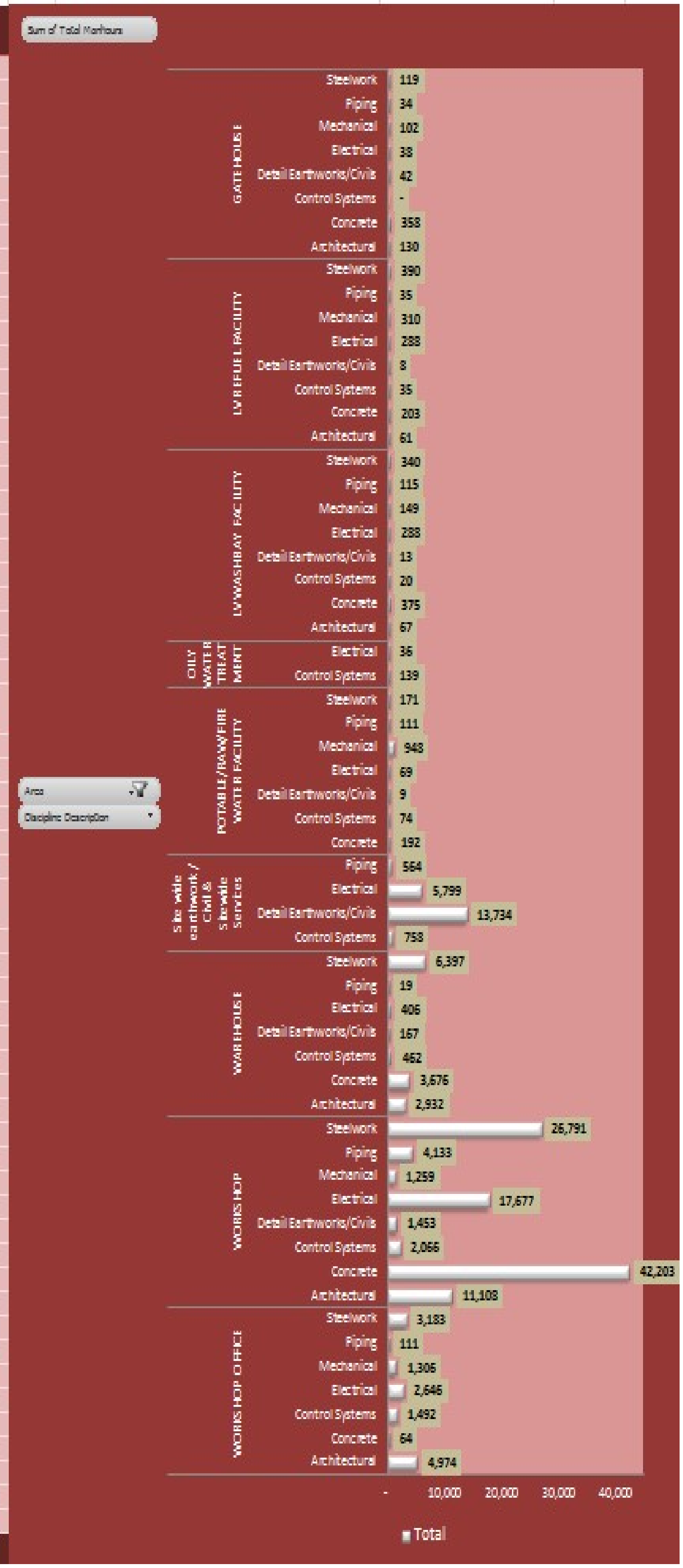
Table 8-14 Direct Hours Estimates- TOTAL

Discipline	Total
Architectural	19,271
Concrete	47,071
Control Systems	7,538
Detail Earthworks/Civils	15,426
Electrical	27,248
Mechanical	46,506
Piping	5,123
Steelwork	37,392
Grand Total	**205,575**

➢ **NPI**

TABLE 8-15 Direct Hours Estimates- NPI

Area	Discipline Descript	Total
⊟ GATEHOUSE	Architectural	130
	Concrete	358
	Control Systems	-
	Detail Earthworks/Civils	42
	Electrical	38
	Mechanical	102
	Piping	34
	Steelwork	119
⊟ LV REFUEL	Architectural	61
	Concrete	203
	Control Systems	35
	Detail Earthworks/Civils	8
	Electrical	288
	Mechanical	310
	Piping	35
	Steelwork	390
⊟ LV WASHBAY	Architectural	67
	Concrete	375
	Control Systems	20
	Detail Earthworks/Civils	13
	Electrical	288
	Mechanical	149
	Piping	115
	Steelwork	340
⊟ OILY WATER	Control Systems	139
	Electrical	36
⊟ POTABLE/RAW/FIRE WATER FACILITY	Concrete	192
	Control Systems	74
	Detail Earthworks/Civils	9
	Electrical	69
	Mechanical	948
	Piping	111
	Steelwork	171
⊟ / Civil & Sitewide Services	Control Systems	758
	Detail Earthworks/Civils	13,734
	Electrical	5,799
	Piping	564
⊟ WAREHOUSE	Architectural	2,932
	Concrete	3,676
	Control Systems	462
	Detail Earthworks/Civils	167
	Electrical	406
	Piping	19
	Steelwork	6,397
⊟ WORKSHOP	Architectural	11,108
	Concrete	42,203
	Control Systems	2,066
	Detail Earthworks/Civils	1,453
	Electrical	17,677
	Mechanical	1,259
	Piping	4,133
	Steelwork	26,791
⊟ WORKSHOP	Architectural	4,974
	Concrete	64
	Control Systems	1,492
	Electrical	2,646
	Mechanical	1,306
	Piping	111
	Steelwork	3,183
Grand Total		**160,651**



➢ **PE**

TABLE 8-16 Direct Hours- PE

Area	Total
AGV`s	1,915
BOGIE SHOP	7,319
MAINLINE	8,459
OVERALL CONTROL SYSTEM	2,493
Portal Lathes	6,409
STRUCTURAL SHOP	1,864
WHEELSHOP	16,465
Grand Total	44,923

8.9. Long Lead Items

The Procurement process of wheel shop and AGVs have been identified as critical long lead items:

- Wheel shop 56 Weeks
- AGV`s 52 Weeks

The tables below illustrate the process equipment (PE) duration analysis from three specialist equipment vendors. The three quotes were received and evaluated on a commercial and technical compliance basis. Where items were omitted from a quote, they were substituted by a value from the other quotes to enable a fair comparison to be made.

Table 8-17 Lead Time- PE Fabrication

A: PE Fabrication Lead times

Id	Process Equipment Package-RFQ package	Vendor and Duration			Schedule Duration	Comments
		Vendor 1	Vendor 2	Vendor 3		
1	Wheelshop	56 weeks	72 weeks	64 weeks	**56 weeks**	Vendor 1 is recommended bidder for estimate. Most technically complaint. This vendor has recent relevant experience for a project like this in WA.
2	AGVs	52 weeks	40 to 52 weeks	56 weeks	**52 weeks**	Vendor 1 is recommended bidder for estimate. This wendor has underestanding as to the background to the project
3	Main Line	50 weeks	68 weeks	-	**50 weeks**	Vendor 1 is recommended bidder for estimate. Most technically complaint. This vendor has recent relevant experience for a project like this in WA. No basis on the other vendors` provided schedules
4	Bogie Shop		68 weeks	-	**50 weeks**	
5	Structural Shop		56 weeks	-	**30 weeks**	
6	Control Systems		56 weeks	-	**50 weeks**	

Table 8-18 Lead Time- PE Installation

B: PE Installation

Id	Process Equipment Package-RFQ package	Vendor and Duration			Schedule Duration	Comments
		Vendor 1	Vendor 2	Vendor 3		
1	Wheelshop	12 weeks	Not Provided	8 weeks	**12 weeks**	Vendor 1 is recommended bidder for estimate. Most technically complaint. This vendor has recent relevant experience for a project like this in WA.
2	AGVs	4 weeks	4 weeks	Not supplied	**4 weeks**	Vendor 1 is recommended bidder for estimate. This wendor has underestanding as to the background to the project
3	Main Line	50 weeks	10 weeks	-	**10 weeks**	Vendor 1 is recommended bidder for estimate. Most technically complaint. This vendor has recent relevant experience for a project like this in WA. No basis on the other vendors` provided schedules
4	Bogie Shop		10 weeks	-	**10 weeks**	
5	Structural Shop		10 weeks	-	**10 weeks**	
6	Control Systems		10 weeks	-	**10 weeks**	

Table 8-19 Lead Time- PE Commissioning

C: PE Commissioning

Id	Process Equipment Package-RFQ package	Vendor and Duration			Schedule Duration	Comments
		Vendor 1	Vendor 2	Vendor 3		
1	All Process Equipment	20 weeks	10 weeks	16 weeks	**20 weeks**	Vendor 1 is recommended bidder for estimate. Most technically complaint. This vendor has recent relevant experience for a project like this in WA.

8.10. Schedule Activity durations

➢ **Contracting process**

As per the EPCM contract agreement, required durations to complete the contracting process consisting of the below tasks for 3 contract packages are shown in Table 8-20. Engineering approve man-hours associating efficiency factors determine overall duration for each package:

- Preliminary works (Develop Contract/Procurement Plan, Scope of work, and Tender documents). Below is an example for PE:
    - SOW & Spec compilation
    - Procurement plan compilation
    - Procurement plan approved by client
    - SOW & Spec approved by client
    - Tender package compilation
    - Pre-Tender briefing to PE contractors
    - Critical package review meeting
    - Tender package approved by client
    - Finalised tender package
- Tendering period,
- RFA:
    - Tender evaluation
    - Commercial risk review meeting
    - Conform contract/RFA compilation
    - RFA approved by client
    - Contract approved by client
    - Contract award period
- Contract award- NOA

TABLE 8-20 Required Durations- Contracting Process

Activities	Portal Lathes	PE	NPI Works
Preliminaries (Proc. plan, SOW, Tender docs)	8 weeks	10 weeks	13 weeks
Tendering	3 weeks	12 weeks	10 weeks
RFA	7 weeks	13 weeks	18 weeks
Contract Award- NOA	0 week	0 week	0 week
Total	18 weeks	35 weeks	41 weeks

- **Construction- NPI**

The duration of NPI construction activities is estimated based on the quantity of the work, production rate, and number of required direct workforces. Construction productivity assumptions have been derived from historical data as well as the specific factors relating to specific facilities.

The following tables provide schedule durations by rates and quantities per facility and commodity type:

Table 8-21 Construction Production Rate

Production Rates	Average (Mhs/Uom)
Earthworks & Civil	0.32
Concrete	9.51
Structural Steel	54.44

Table 8-22 Average Weekly Quantities

Weekly Quantities	Average (Qty/Week)
Earthworks & Civil - M3	1340
Concrete - M3	193
Structural Steel - Ton	42
Architectural – M2	669
Piping - LM	140
Electrical - LM	1542
Control System - LM	552

Table 8-23 Planned Quantities- Weekly Usage

Weekly Quantities	Average (Qty/Week)	1-Feb-14	1-Mar-14	1-Apr-14	1-May-14	1-Jun-14	1-Jul-14	1-Aug-14	1-Sep-14	1-Oct-14	1-Nov-14	1-Dec-14	1-Jan-15	1-Feb-15	1-Mar-15	1-Apr-15
Earthworks & Civil	**1340**	515	1223	840	5	37	6	3		4955	5385	431				
Concrete	**193**			165	519	326	56	3	263	19						
Structural Steel	**42**				40	60	65	41	2							
Architectural	**669**					873	843	828	659	141						
Piping	**140**	88	203	68	4	14	117	287	283	233	100					
Electrical	**1542**	105	243	233	312	40	1360	4326	3880	4449	1993	26				
Control Systems	**552**	307	709	238			266	818	696	1148	236					

TABLE 8-24 Planned Production Rate- Weekly

Production Rates	Average (Mhs/Uom)	1-Feb-14	1-Mar-14	1-Apr-14	1-May-14	1-Jun-14	1-Jul-14	1-Aug-14	1-Sep-14	1-Oct-14	1-Nov-14	1-Dec-14	1-Jan-15	1-Feb-15	1-Mar-15	1-Apr-15
Earthworks & Civil	**0.32**	0.45	0.47	0.67	0.37	0.07	0.22	0.27		0.23	0.23	0.23				
Concrete	**9.51**			7.70	8.33	9.04	9.32	13.25	9.48	9.45						
Structural Steel	**50.44**				40.92	40.79	43.09	57.53	69.86							
Architectural	**1.80**					0.89	0.95	1.73	1.89	3.52						
Piping	**0.75**	0.38	0.38	0.38	0.43	0.41	0.97	1.19	1.12	1.10	1.12					
Electrical	**0.61**	0.94	0.94	0.94	0.92	0.19	0.32	0.34	0.35	0.40	0.46	0.94				
Control Systems	**0.30**	0.15	0.15	0.15			0.30	0.21	0.32	0.40	0.69					

Table 8-25 Main Workshop PR Estimates

OCRS Average Production Rate for (Main Workshop + Admin Office)											
Id	Location	Commodity	Activity	Working Days	Quantities			Staff		Average (Mhs/UOM)	Note
					UoM	Qty.	Ave. Productivity (Qty/day)	Total Hours	Number of Staff		
1	Workshop + office	A0	Detailed Earth work	20	M3	1,420	71	1452	9	1.02	Includes Excavation for foundation , Preparation for the slab, Waterproofing and Backfilling
2		A1	Foundation	31	M3	875	28	5822	23	6.65	Includes Form working , Reinforcement, Anchor bolts, Blinding and Concrete Placement for footings and Pits
3		A1	Slab	75	M3	3,843	51	36466	61	9.49	Includes Form working , Reinforcement, Blinding and Concrete Placement
4		A2	Steel Structure	70	Ton	724	10	29983	54	41.41	Includes erection and fixing of columns, beams and purlins
5		A3	Architectural	85	M2	11,973	141	16095	24	1.34	Includes fixing of cladding to walls and roof, roof ventilators and ancillaries.
6		A6	Piping	96	M	3,716	39	6846	9	1.84	Includes Hydraulic ,Mech. Equipment Installation , Piping & tests
7		A7	Electrical	96	M	57,761	602	20344	26	0.35	Includes fixing cable ladders, distribution boards, equipment and installation and termination of communications and power cables.
8		A8	Control System	96	M	9,449	98	3651	5	0.39	

➢ **Fabrication & Delivery- PE**

There has not been any specific benchmarking completed on the process equipment packages as the scope is considered unique (i.e. "one off").

Rather than benchmarking against previous projects, experienced suppliers of this type of equipment provided written advice on their expected manufacture installation and commissioning schedule as part of the request for quotation process.

The comparison of schedule durations provided by the preferred suppliers address the following tasks:

- Design
- Supply & Manufacture
- Factory acceptance test (FAT)
- Freight

Table 8-26 is the summary of the required durations from design process to unload in WA for the wheel shop and AGVs. PE transport to site is not included in the below estimates:

Table 8-26 Required Duration- Wheel shop and AGVs

Activities	Wheelshop	AGVs
Design	12 weeks	14 weeks
Supply & Manufacture	36 weeks	30 weeks
FAT	2 weeks	2 weeks
Freight	6 weeks	6 weeks
Total	56 weeks	52 weeks

➢ **Installation & Commissioning - PE**

Process equipment required duration for installation & commissioning are quoted from 3 preferred vendors detailed in Tables 8-18 and 8-19.

8.11. Schedule Assumptions

- Pre-commitment funding is available to progress engineering and commercial documentation ready for tender for all contract packages
- The durations for design, manufacture, assembly, FAT, installation, and commissioning of process equipment is based on the information received from the suppliers during the RFQ process
- Construction of workshop and associated services will allow incremental completion of commissioned zones of the workshop to enable the process equipment to be installed
- Construction of other buildings, facilities and finishing works can be scheduled to occur concurrently as the site layout and availability of construction resources (e.g. accommodation) will not be constrained
- Early occupation and use of permanent infrastructure by operations is not required
- Statutory approval will not delay the project
- The NPI construction durations have been validated by RFQ responses from several tier 2 contractors
- The portal lathes will be sole sourced and have 15-month manufacture and acceptance cycle. There is a manufacturing constraint that prevents multiple lathes being manufactured in parallel. This results in 3-month lag in the completion of each unit
- The long lead subcomponents for the two portal lathes have already been ordered which reduces the cycle time for the first lathe
- The portal lathe installation and commissioning durations have been provided by the portal lathe manufacturer
- Accommodation is to be provided by Client. No temporary works and services for the provision of accommodation are allowed for in the schedule
- The NPI detailed design, planning, pre-construction, and site establishment activities is based on the following assumptions:
  - 20 weeks for detail design

- 6 weeks for contractor planning and pre-construction activities
- 5 weeks for site establishment following completion of the necessary planning and pre-construction activities such as approvals, subcontractor engagement
- Construction of workshop and associated services commences after site establishment and will take approximately 8 months to construct and commission
- Commissioning of the NPI in the workshop Zone A area will commence approximately 7 months after the commencement of the workshop. Commissioning of the NPI is scheduled to take 2 weeks
- All process equipment will be available on the day that process equipment installation is scheduled to commence within each respective workshop stage
- The process equipment installation will commence once each stage of the workshop has been commissioned, and
- The NPI contractor will be responsible for detailed scheduling and resourcing of the installation of the process equipment within the window of duration provided in the master schedule

8.12. Key interfaces & Milestones

The key interface between the EPCM schedule and associated contractor`s schedule are as follows (these will be considered as major milestones and will derive project forecast dates and critical paths):

- NPI possession of site would be after completion of constructing access road, bulk earth works, and large cut-off drain at end of October 13
- Availability of construction water, portable water and wastewater system by another contractor by end of October 13
- Power supply to the site will be provided by 14 June 14
- Installation of process equipment can be commenced after completion and commissioning of Zone A workshop. This will be under the supervision of PE contractor. The target completion date of zone A construction is 02 Oct 14

- Upon completion of installation of the process equipment by the NPI contractor, commissioning will commence. The commissioning of the PE will be carried out by the PE contractor. The target completion date of PE installation is 04 Apr 15
- The hand-over date to client operation following successful completion of ramp up is 11 Nov 15

8.13. Constraints

The constraints [Frigenti E. Comninos D, 2002] used in the schedule development are listed in Table 8-27.

TABLE 8-27 Project Constraints

Constraints				
Activity ID	Activity Name	Constraint Type	Date	Basis of Constraint
Interface Milestone (As Scheduled by Calibre)				
62-EP-M-1930	Earthworks and Building Pad Complete (Site Handover) (Calibre Act ID : 62EPM12085)	Finish On or After	31-Oct-13*	Interface Constraint
62-EP-M-2000	Raw & Potable Water (For Construction Period) / Access Road Complete (Calibre Act ID : 62EPM12035, 62EPM12095)	Finish On or After	31-Oct-13*	Interface Constraint
62-EP-M-2010	HV Power Connection to OCRS Complete (Calibre Act ID : 62EPM12215)	Finish On or After	14-Jun-14*	Interface Constraint
62-EP-M-2020	Rail Works & Signalling Complete (Calibre Act ID : 62EPM12225)	Finish On or After	10-Aug-14*	Interface Constraint
Other Buildings, Facilities and Finishing Works				
62-EP-M-3060	Commissioning Complete - Warehouse- FSH	Finish On	8-Jan-15*	Constraint to limit float for 6 weeks
62-EP-M-3070	Commissioning Complete - Gatehouse- FSH	Finish On	9-Aug-14*	Constraint to limit float for 6 weeks
62-EP-M-3080	Commissioning Complete - LV Refuel Facility - FSH	Finish On	11-Sep-14*	Constraint to limit float for 6 weeks
62-EP-M-3090	Commissioning Complete - Light Vehicle Wash- FSH	Finish On	29-Sep-14*	Constraint to limit float for 6 weeks
62-EP-M-3100	Commissioning Complete - Oily Water Treatment Plant - FSH	Finish On	18-Sep-14*	Constraint to limit float for 6 weeks
62-EP-M-3110	Commissioning Complete - Potable/Raw/Fire Water Facility - FSH	Finish On	29-Nov-14*	Constraint to limit float for 6 weeks
62-EP-M-3140	Commissioning Complete - Landscaping & Finishing Works - FSH	Finish On	3-Feb-15*	Constraint to limit float for 6 weeks

8.14. Schedule logic and sequence

The logic and sequence defined for the schedule activities will determine early & late forecast dates, critical path, summary tasks duration, total floats, free floats and project required duration. This logic should reflect project construction method, contract & procurement strategies, and client required procedures to meet the targeted completion dates.

All the leads & lags, logic, and dummy links shall be documented in the project basis of schedule document. Below is the general sequence for the typical EPCM contracts:

- **NPI**

Drawings & specifications required for tendering purpose can be issued in 7 weeks. During the engineering phase, preliminary works of contracting process can commence and subsequently tendering and request for approval (RFA) tasks will be next to get the contract ready for award to the preferred contractor.

The next stage after contract notice of award (NOA) will be the contractor`s site establishment & early works, detailed designs, construction of underground services, construction of NPI components as per project WBS, and installation of process equipment (PE). Below, Figure 8.3 shows the summary of NPI activities sequence to be defined in the project schedule.

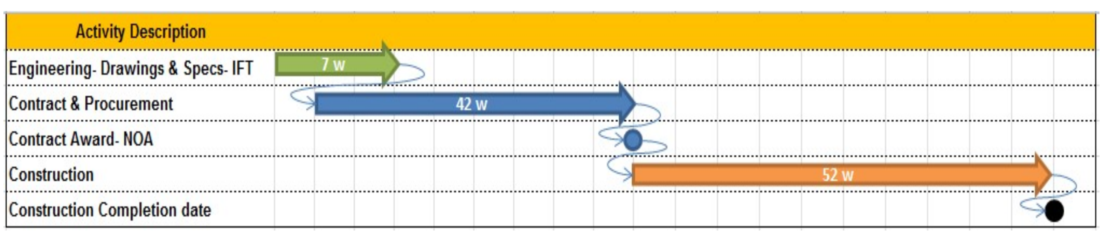


FIGURE 8-3 NPI Activities Sequences

- **PE**

Drawings & specifications required for tendering purpose can be issued in 13 weeks. The below Figure 8-4 demonstrates typical logic for engineering, contracting, fabrication & deliveries, installation, commissioning, and ramp up phases of project process equipment.

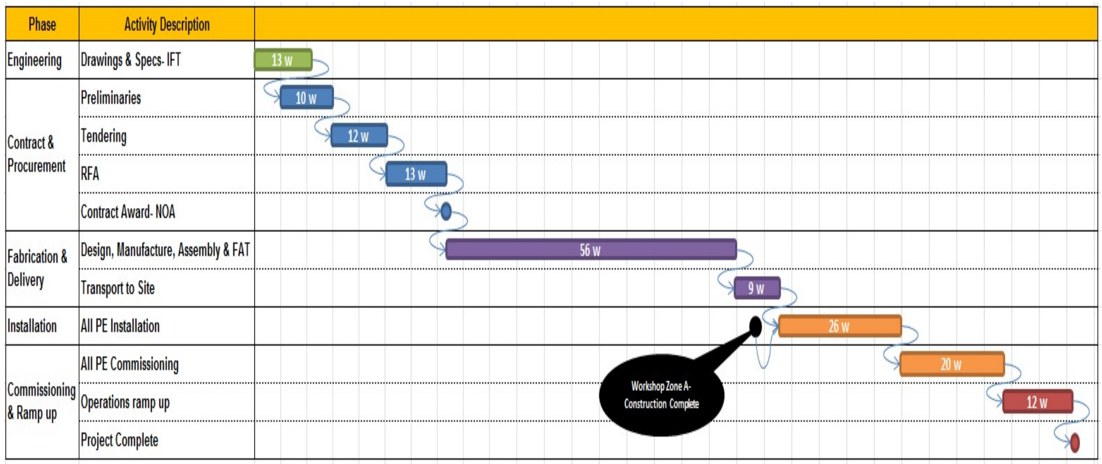


FIGURE 8-4 **EPCM Activities Sequence**

8.15. Project Schedule

The project schedule is one of the key deliverables of project time management process that represents linked activities, durations, resources, milestones, and planned dates. According to the project management body of knowledge [PMBOK Guide Fifth Edition, 2013], the following processes shall be carried for the project's time management component

- **Plan schedule management:** this document refers to how to plan, develop, manage, execute, and control the project schedules. The project charter, project management plan, and organizational assets are the key input to establishing this document. They describe the following:
  - Unit of measures
  - Level of accuracy
  - Schedule model development
  - Organizational procedures links
  - Control thresholds
  - Schedule maintenance method
  - Reporting format
  - Rule of performance measurements
  - Process description

- **Define activities:** Identifying and documenting project tasks to be performed to produce the project deliverables
- **Sequence activities:** Identifying and documenting relationships among the project activities
- **Estimate activity resources:** Estimating the type and quantities of materials, equipment, and workforces required to perform each activity
- **Estimate activity durations:** estimating the number of work periods needed to complete individual activities with estimated resources
- **Develop schedule:** the process of analysing the project schedule to develop a project schedule model
- **Control schedule:** the process of monitoring the status of project activities to update project progress and manage changes to schedule baseline to meet the plan. To run the schedule monitoring process, the project management plan, project schedule, work performance data, project calendars, schedule data, and organizational procedures are required

Below is the summary of project time management overview including the main inputs and process illustrated in Figure 8-5 [Vargas R, 2008].

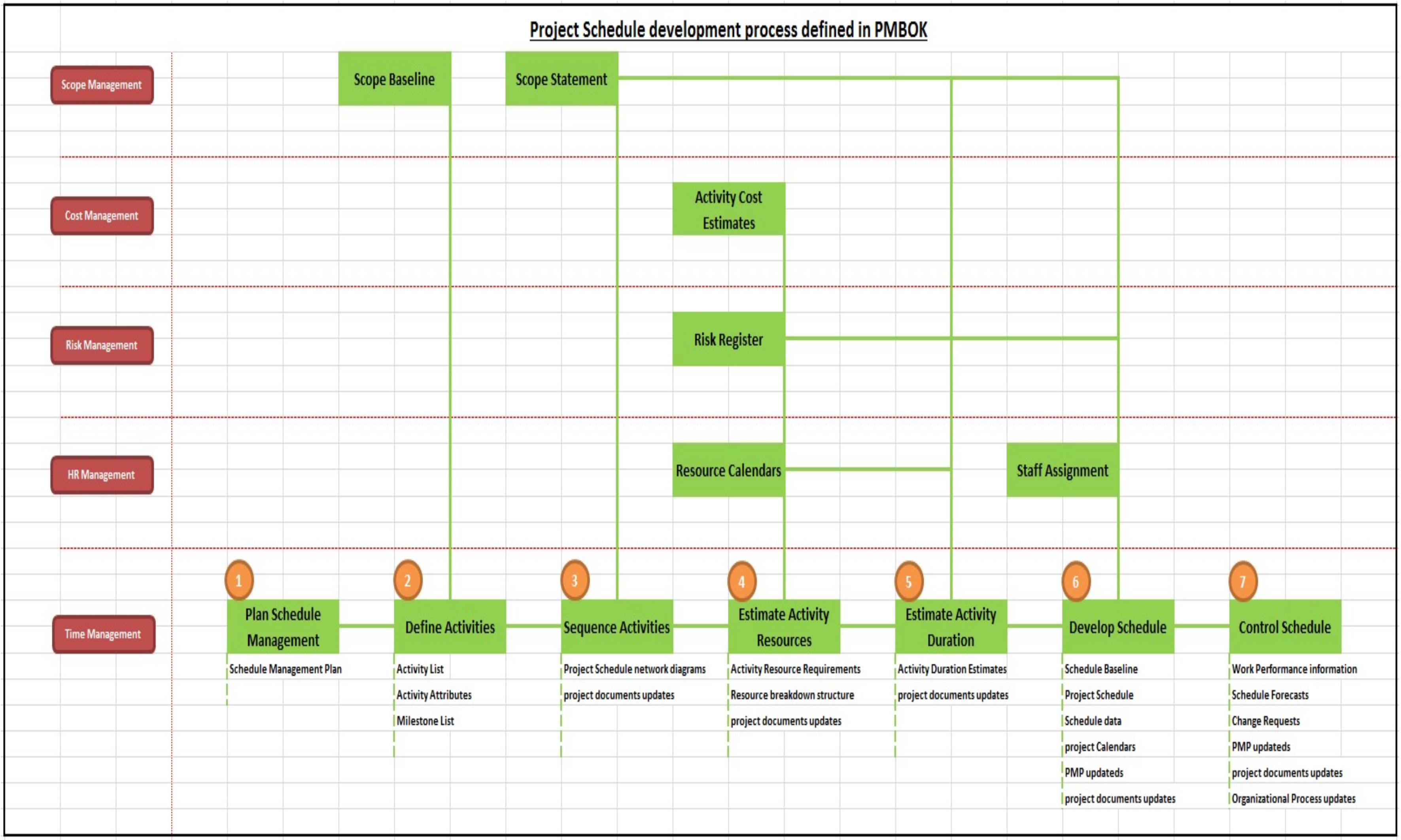


Figure 8-5 Project Schedule Development Process

Following scheduling standard practice, the critical path method (CPM) concept (makes use of estimated task durations with no regard for probabilities)[Lewis,J,2001] is used to generate OCRS schedule. This technique calculates the early dates, late dates, project duration, and floats for all schedule activities without consideration of resource constraints by conducting forward & backward pass analysis through the schedule network.

After executing CPM, it is important to adjust activity planned dates based on the availability of resources and agreed limits. There are multiple techniques to be used for resource levelling to keep the resource usage at a constant level. In this example, schedule activities' total floats and free floats have been applied to optimize project resources, to meet the project completion target date, and to keep project baseline cost estimates.

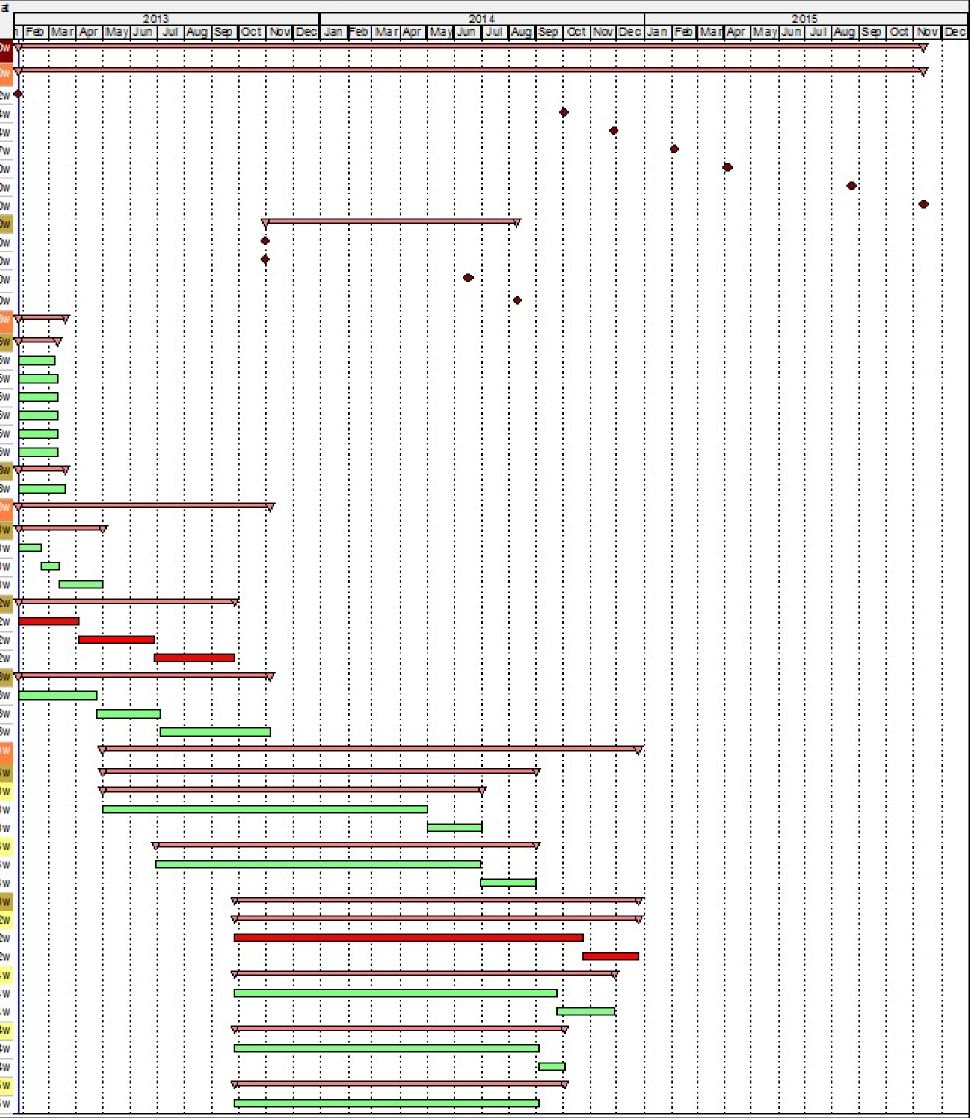
Once the project schedule is approved by all stakeholders, it can be considered as a schedule baseline [Mubarak S,2010] that can be varied only through formal change control procedures and is used as a basis for performance comparison to actual results.

The OCRS baseline plan illustrated in Figure 8-6 has been prepared by the agreed and endorsed project management software (Primavera P6) that will be a basis of delay analysis, schedule performance measurement, team performance measurement, planned progress curves, baseline cash flow, planned resource requirements, sub-contractor time management etc.

Ore Car Repair Shop Execution Schedule

Data Date: 25-Jan-13

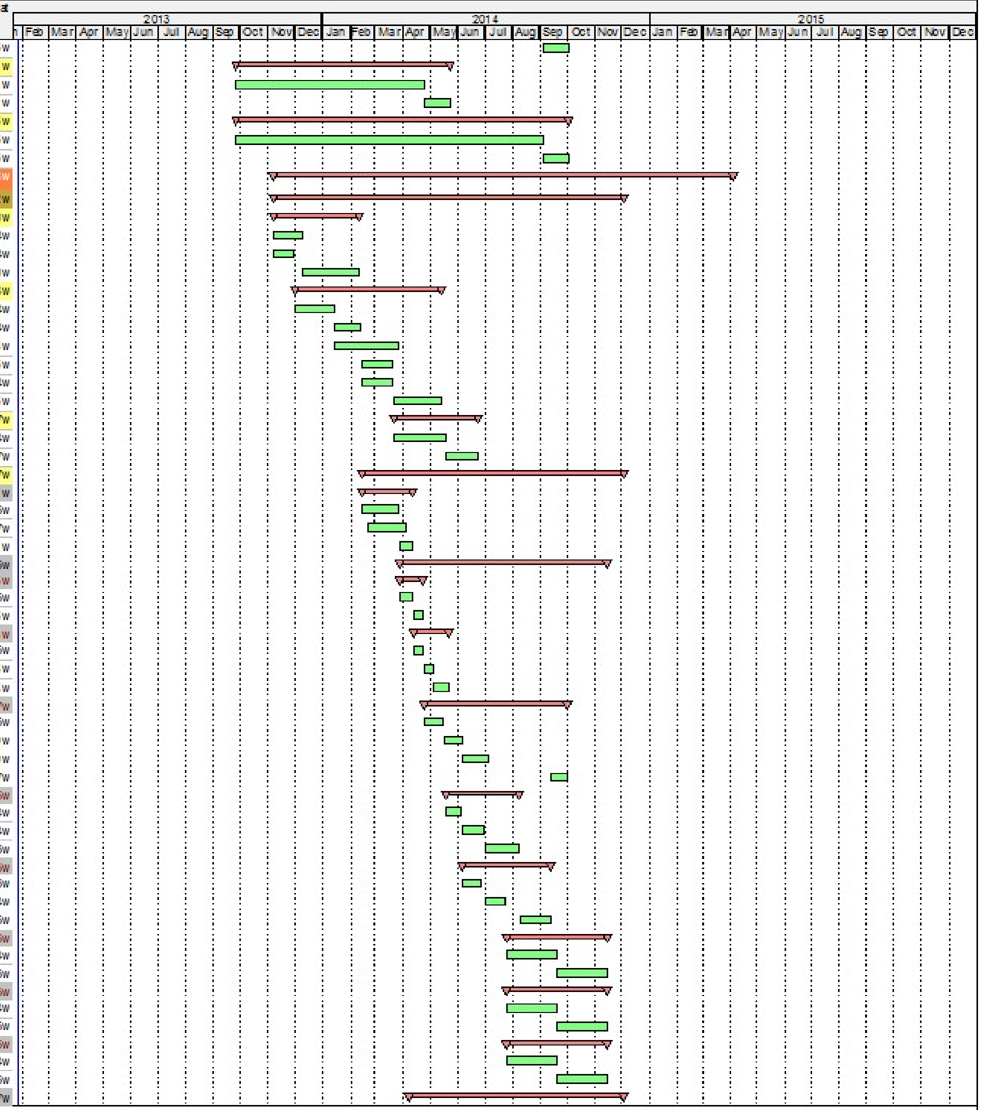
Activity ID	Activity Name	Original Duration	Start	Finish	Activity % Complete	Total Float
Ore Car Repair Shop Execution Schedule		141w	25-Jan-13 08	11-Nov-15 14		0w
Milestones		141w	25-Jan-13 08	11-Nov-15 14		0w
OCRS-M-1000	Project Start	0w	25-Jan-13 08		0%	2w
OCRS-M-1060	Main Workshop Building Completion - Zone A	0w		02-Oct-14 16	0%	4w
OCRS-M-1100	Main Workshop Building Completion - Zone B	0w		28-Nov-14 16	0%	4w
OCRS-M-1070	NPI Commissioning Complete	0w		03-Feb-15 16	0%	7w
OCRS-M-1080	PE Installation Complete	0w		04-Apr-15 16	0%	0w
OCRS-M-1090	PE Commissioning Complete	0w		22-Aug-15 14	0%	0w
OCRS-M-1010	Handover to Client	0w		11-Nov-15 14	0%	0w
Interface Milestone - From Other Contractors		40w	31-Oct-13 08	11-Aug-14 08		0w
OCRS-M-1020	Earthworks and Building Pad complete (Site Handover)	0w		31-Oct-13 08*	0%	0w
OCRS-M-1030	Raw & Potable water (for construction period) / Access road cor	0w		31-Oct-13 08*	0%	0w
OCRS-M-1040	HV Power connection to project complete	0w		16-Jun-14 08*	0%	0w
OCRS-M-1050	Rail works & Signalling complete	0w		11-Aug-14 08*	0%	0w
Engineering for D&C Tender		7w	25-Jan-13 08	20-Mar-13 16		8w
Contract Package 02 - Process Equipment		6w	25-Jan-13 08	11-Mar-13 16		5w
OCRS-E-1000	Engineering - Wheelshop Drawings & Specs - IFT	6w	25-Jan-13 08	07-Mar-13 16	0%	5w
OCRS-E-1020	Engineering - AGV's Drawings & Specs - IFT	6w	25-Jan-13 08	11-Mar-13 16	0%	5w
OCRS-E-1030	Engineering - Bogie Shop Drawings & Specs - IFT	6w	25-Jan-13 08	11-Mar-13 16	0%	5w
OCRS-E-1040	Engineering - Mainline Drawings & Specs - IFT	6w	25-Jan-13 08	11-Mar-13 16	0%	5w
OCRS-E-1050	Engineering - Stuctual Shop Drawings & Specs - IFT	6w	25-Jan-13 08	11-Mar-13 16	0%	5w
OCRS-E-1060	Engineering - Overall Control System Drawings & Specs - IFT	6w	25-Jan-13 08	11-Mar-13 16	0%	5w
Contract Package 03 - NPI Works		7w	25-Jan-13 08	20-Mar-13 16		8w
OCRS-E-1010	Engineering - NPI Works Drawings & Specs - IFT	7w	25-Jan-13 08	20-Mar-13 16	0%	8w
Contracts & Procurement		40w	25-Jan-13 08	06-Nov-13 16		3w
Contract Package 01 - Portal Lathes		13w	25-Jan-13 08	30-Apr-13 16		20w
OCRS-P-1000	Contract Package 01 - Portal Lathes - Preliminaries	3w	25-Jan-13 08	19-Feb-13 16	0%	20w
OCRS-P-1010	Contract Package 01 - Portal Lathes - Tendering	3w	20-Feb-13 08	12-Mar-13 16	0%	20w
OCRS-P-1020	Contract Package 01 - Portal Lathes - RFA and Contract Award (	7w	13-Mar-13 08	30-Apr-13 16	0%	20w
Contract Package 02 - Process Equipment		34w	25-Jan-13 08	26-Sep-13 16		2w
OCRS-P-1030	Contract Package 02 - Process Equipment - Preliminaries	9w	25-Jan-13 08	03-Apr-13 16	0%	2w
OCRS-P-1040	Contract Package 02 - Process Equipment - Tendering	12w	04-Apr-13 08	27-Jun-13 16	0%	2w
OCRS-P-1050	Contract Package 02 - Process Equipment - RFA and Contract A	13w	28-Jun-13 08	26-Sep-13 16	0%	2w
Contract Package 03 - NPI Works		40w	25-Jan-13 08	06-Nov-13 16		3w
OCRS-P-1060	Contract Package 03 - NPI Works - Preliminaries	12w	25-Jan-13 08	23-Apr-13 16	0%	3w
OCRS-P-1070	Contract Package 03 - NPI Works - Tendering	10w	24-Apr-13 08	03-Jul-13 16	0%	3w
OCRS-P-1080	Contract Package 03 - NPI Works - RFA and Contract Award (N	18w	04-Jul-13 08	06-Nov-13 16	0%	3w
Fabrication & Delivery		86w	30-Apr-13 16	25-Dec-14 16		10w
Contract Package 01 - Portal Lathes		70w	30-Apr-13 16	01-Sep-14 16		23w
First Lathe		61w	30-Apr-13 16	02-Jul-14 16		20w
OCRS-F-1020	Contract Package 01 - First Portal Lathe - Design,Manufacture,	52w	30-Apr-13 16	30-Apr-14 16	0%	20w
OCRS-F-1030	Contract Package 01 - First Portal Lathe - Transport to Site	9w	30-Apr-14 16	02-Jul-14 16	0%	20w
Second Lathe		61w	29-Jun-13 16	01-Sep-14 16		23w
OCRS-F-1040	Contract Package 01 - Senond Portal Lathe - Design,Manufact	52w	29-Jun-13 16	30-Jun-14 16	0%	23w
OCRS-F-1050	Contract Package 01 - Senond Portal Lathe - Transport to Site	9w	30-Jun-14 16	01-Sep-14 16	0%	23w
Contract Package 02 - Process Equipment		65w	26-Sep-13 16	25-Dec-14 16		10w
Wheel Shop		65w	26-Sep-13 16	25-Dec-14 16		2w
OCRS-F-1000	Contract Package 02 - Wheel Shop - Design,Manufacture, Ass	56w	26-Sep-13 16	23-Oct-14 16	0%	2w
OCRS-F-1010	Contract Package 02 - Wheel Shop - Transport to Site	9w	23-Oct-14 16	25-Dec-14 16	0%	2w
AGV's		61w	26-Sep-13 16	27-Nov-14 16		14w
OCRS-F-1060	Contract Package 02 - AGV's - Design, Manufacture, Assembly	52w	26-Sep-13 16	25-Sep-14 16	0%	14w
OCRS-F-1070	Contract Package 02 - AGV's - Transport to Site	9w	25-Sep-14 16	27-Nov-14 16	0%	14w
Bogie Shop		53w	26-Sep-13 16	02-Oct-14 16		4w
OCRS-F-1080	Contract Package 02 - Bogie Shop - Design,Manufacture, Asse	49w	26-Sep-13 16	04-Sep-14 16	0%	4w
OCRS-F-1090	Contract Package 02 - Bogie Shop - Transport to Site	4w	04-Sep-14 16	02-Oct-14 16	0%	4w
Main Line		53w	26-Sep-13 16	02-Oct-14 16		16w
OCRS-F-1100	Contract Package 02 - Main Line - Design,Manufacture, Asser	49w	26-Sep-13 16	04-Sep-14 16	0%	16w



Actual Work — Critical Remaining Work — Summary
Remaining Work — Milestone

TASK filter: All Activities
Layout: OCRS

Activity ID	Activity Name	Original Duration	Start	Finish	Activity % Complete	Total Float
OCRS-F-1110	Contract Package 02 - Main Line - Transport to Site	4w	04-Sep-14 16	02-Oct-14 16	0%	16w
Structural Shop		34w	26-Sep-13 16	22-May-14 16		41w
OCRS-F-1120	Contract Package 02 - Structural Shop - Design,Manufacture,A	30w	26-Sep-13 16	24-Apr-14 16	0%	41w
OCRS-F-1130	Contract Package 02 - Structural Shop - Transport to Site	4w	24-Apr-14 16	22-May-14 16	0%	41w
Control System		53w	26-Sep-13 16	02-Oct-14 16		16w
OCRS-F-1140	Contract Package 02 - Control System - Design,Manufacture,A	49w	26-Sep-13 16	04-Sep-14 16	0%	16w
OCRS-F-1150	Contract Package 02 - Control System - Transport to Site	4w	04-Sep-14 16	02-Oct-14 16	0%	16w
Construction & Installation		73w	07-Nov-13 08	04-Apr-15 16		38w
Site Establishment , Main Workshop and other Non Process Infrastruc		59w	07-Nov-13 08	02-Dec-14 16		52w
Site establishment & Enabling Works		11w	07-Nov-13 08	11-Feb-14 16		100w
OCRS-I-1000	Construction - Planning and Pre-construction Activities	6w	07-Nov-13 08	09-Dec-13 16	0%	4w
OCRS-I-1010	Construction - Establish Home Office Design team and Construc	4w	07-Nov-13 08	29-Nov-13 16	0%	4w
62-EP-I-4370	Construction - Early Works and Site Establishment	5w	10-Dec-13 08	11-Feb-14 16	0%	100w
D&C Contractor's Detailed Engineering		20w	30-Nov-13 08	12-May-14 16		28w
OCRS-I-1020	Construction - Detailed Design - AFC Drawings - Civil & UG serv	3w	30-Nov-13 08	14-Jan-14 16	0%	4w
OCRS-I-1030	Construction - Detailed Design - AFC Drawings - Civil, Earthwor	4w	15-Jan-14 08	12-Feb-14 16	0%	4w
OCRS-I-1040	Construction - Detailed Design - AFC Drawings - Architectural	10w	15-Jan-14 08	27-Mar-14 16	0%	24w
62-EP-I-4380	Construction - Detailed Design - AFC Drawings - Mechanical &	5w	13-Feb-14 08	20-Mar-14 16	0%	36w
OCRS-I-1050	Construction - Detailed Design - AFC Drawings - Structural	5w	13-Feb-14 08	20-Mar-14 16	0%	4w
62-EP-I-4390	Construction - Detailed Design - AFC Drawings - Electrical & Ins	8w	21-Mar-14 08	12-May-14 16	0%	25w
Fabrication of Steel Structure		15w	21-Mar-14 08	23-Jun-14 16		7w
OCRS-I-1060	Construction - Fabrication of Steel Structure - Zone A	9w	21-Mar-14 08	17-May-14 16	0%	4w
OCRS-I-1070	Construction - Fabrication of Steel Structure - Zone B	6w	19-May-14 08	23-Jun-14 16	0%	7w
Main Workshop and other NPI		48w	13-Feb-14 08	02-Dec-14 16		7w
Sitewide underground Services		8w	13-Feb-14 08	11-Apr-14 16		11w
OCRS-I-1080	Construction - Underground Services (Workshop & Warehouse	6w	13-Feb-14 08	27-Mar-14 16	0%	5w
OCRS-I-1090	Construction - Underground Services (Gatehouse, FM, and HV	6w	21-Feb-14 08	05-Apr-14 16	0%	7w
OCRS-I-1100	Construction - Underground Services (LV area)	2w	28-Mar-14 08	11-Apr-14 16	0%	11w
OCRS Main Workshop		39w	28-Mar-14 08	14-Nov-14 16		5w
Detailed Earthworks		4w	28-Mar-14 08	23-Apr-14 16		26w
OCRS-I-1110	Construction - Surveying & detailed Earthworks - Zone A	2w	28-Mar-14 08	11-Apr-14 16	0%	5w
OCRS-I-1120	Construction - Surveying & detailed Earthworks - Zone B	2w	12-Apr-14 08	23-Apr-14 16	0%	26w
Foundations		6w	12-Apr-14 08	21-May-14 16		24w
OCRS-I-1130	Construction - Foundation Works - Zone A1	2w	12-Apr-14 08	23-Apr-14 16	0%	5w
OCRS-I-1140	Construction - Foundation Works - Zone A2	2w	24-Apr-14 08	05-May-14 16	0%	24w
OCRS-I-1150	Construction - Foundation Works - Zone B	3w	06-May-14 08	21-May-14 16	0%	24w
Ground Slab		27w	24-Apr-14 08	01-Oct-14 16		7w
OCRS-I-1160	Construction - Ground Slab - Zone A1	4w	24-Apr-14 08	15-May-14 16	0%	5w
OCRS-I-1170	Construction - Ground Slab - Zone A2	4w	16-May-14 08	06-Jun-14 16	0%	19w
OCRS-I-1180	Construction - Ground Slab - Zone B	5w	07-Jun-14 08	04-Jul-14 16	0%	19w
OCRS-I-1190	Construction - Ground Slab - Hardstand area	3w	13-Sep-14 08	01-Oct-14 16	0%	7w
Steel Structure		14w	19-May-14 08	08-Aug-14 16		6w
OCRS-I-1200	Construction - Steel Structure - Zone A1	3w	19-May-14 08	05-Jun-14 16	0%	4w
OCRS-I-1210	Construction - Steel Structure - Zone A2	4w	06-Jun-14 08	30-Jun-14 16	0%	4w
OCRS-I-1220	Construction - Steel Structure - Zone B	7w	01-Jul-14 08	08-Aug-14 16	0%	6w
Roofing & Cladding		17w	06-Jun-14 08	12-Sep-14 16		6w
OCRS-I-1230	Construction - Roofing & Cladding - Zone A1	4w	06-Jun-14 08	27-Jun-14 16	0%	5w
OCRS-I-1240	Construction - Roofing & Cladding - Zone A2	4w	01-Jul-14 08	24-Jul-14 16	0%	4w
OCRS-I-1250	Construction - Roofing & Cladding - Zone B	6w	09-Aug-14 08	12-Sep-14 16	0%	6w
Mechanical Works		19w	25-Jul-14 08	14-Nov-14 16		5w
OCRS-I-1260	Construction - Mechanical & Piping works - Zone A	10w	25-Jul-14 08	18-Sep-14 16	0%	4w
OCRS-I-1270	Construction - Mechanical & Piping works - Zone B	10w	19-Sep-14 08	14-Nov-14 16	0%	5w
Electrical Works		19w	25-Jul-14 08	14-Nov-14 16		5w
OCRS-I-1280	Construction - Electrical works - Zone A	10w	25-Jul-14 08	18-Sep-14 16	0%	4w
OCRS-I-1300	Construction - Electrical works - Zone B	10w	19-Sep-14 08	14-Nov-14 16	0%	5w
Architectural Works		19w	25-Jul-14 08	14-Nov-14 16		5w
OCRS-I-1310	Construction - Architectural works - Zone A	10w	25-Jul-14 08	18-Sep-14 16	0%	4w
OCRS-I-1320	Construction - Architectural works - Zone B Incl. Admin Mezzan	10w	19-Sep-14 08	14-Nov-14 16	0%	5w
Other Buildings, Facilities and Finishing Works		40w	07-Apr-14 08	02-Dec-14 16		7w



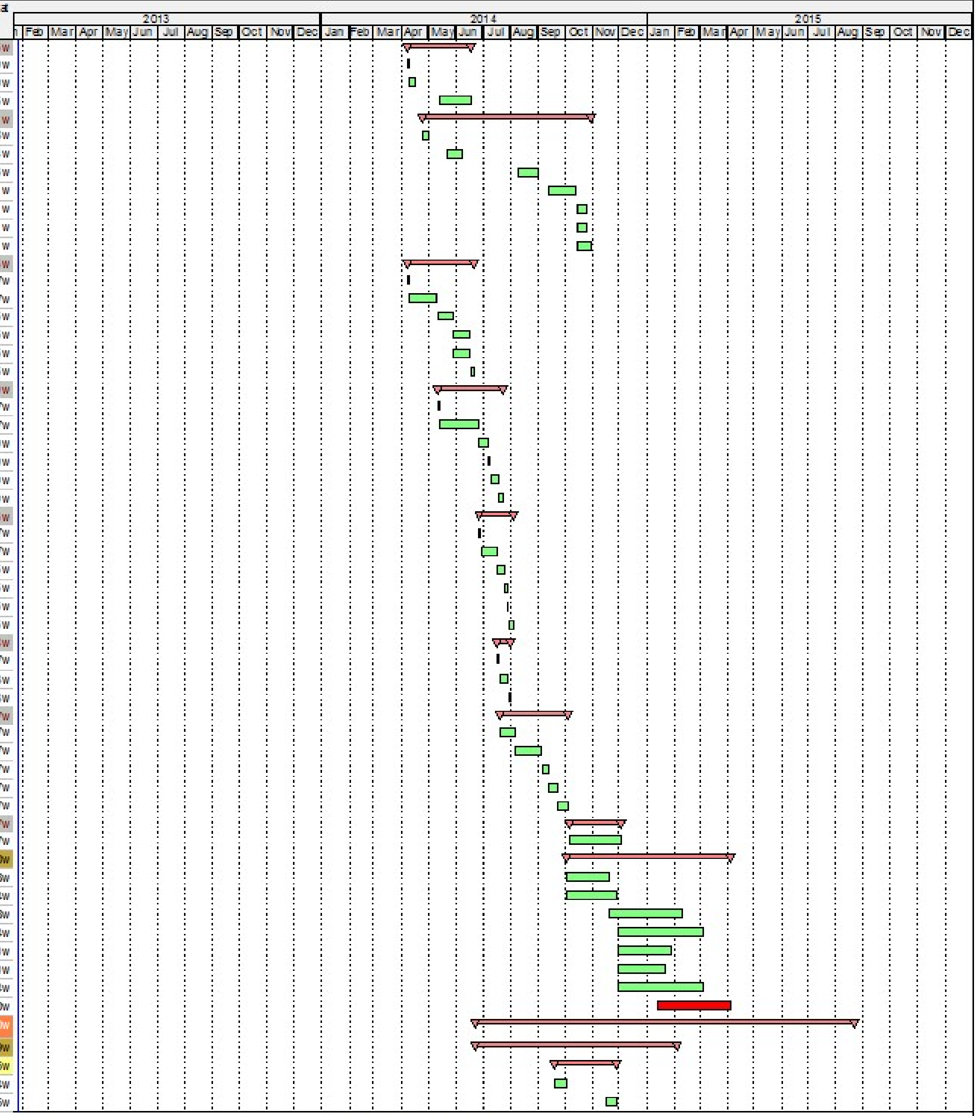
Actual Work | Critical Remaining Work | Summary | Remaining Work | Milestone

TASK filter: All Activities
Layout: OCRS

Ore Car Repair Shop Execution Schedule

Data Date: 25-Jan-13

Activity ID	Activity Name	Original Duration	Start	Finish	Activity % Complete	Total Float
Transformer Kiosks		12w	07-Apr-14 08	17-Jun-14 16		25w
OCRS-I-1330	Construction - Transformer Kiosk- Surveying and detailed Earthw	1w	07-Apr-14 08	09-Apr-14 16	0%	29w
OCRS-I-1340	Construction - Transformer Kiosk- Foundation Works	1w	10-Apr-14 08	15-Apr-14 16	0%	29w
OCRS-I-1350	Construction - Transformer Kiosk- Install Kiosks incl. Electrical	6w	13-May-14 08	17-Jun-14 16	0%	25w
Warehouse		32w	24-Apr-14 08	30-Oct-14 16		11w
OCRS-I-1360	Construction - Warehouse- Surveying and detailed Earthworks	1w	24-Apr-14 08	30-Apr-14 16	0%	28w
OCRS-I-1370	Construction - Warehouse- Foundation works, Ground slab, Cas	3w	22-May-14 08	07-Jun-14 16	0%	24w
OCRS-I-1380	Construction - Warehouse- Steel Structure	4w	09-Aug-14 08	01-Sep-14 16	0%	13w
OCRS-I-1390	Construction - Warehouse- Roofing & Cladding	5w	13-Sep-14 08	13-Oct-14 16	0%	11w
OCRS-I-1400	Construction - Warehouse- Mechanical Works	2w	14-Oct-14 08	24-Oct-14 16	0%	11w
OCRS-I-1410	Construction - Warehouse- Electrical Works	2w	14-Oct-14 08	24-Oct-14 16	0%	11w
OCRS-I-1420	Construction - Warehouse- Architectural Works	3w	14-Oct-14 08	30-Oct-14 16	0%	11w
Gate House		12w	07-Apr-14 08	21-Jun-14 16		35w
OCRS-I-1430	Construction - Gate House-Surveying and detailed Earthworks	0w	07-Apr-14 08	08-Apr-14 16	0%	7w
OCRS-I-1440	Construction - Gate House-Foundation works, Ground slab, Ca:	5w	09-Apr-14 08	10-May-14 16	0%	7w
OCRS-I-1450	Construction - Gate House-Modular system installation & Verar	3w	12-May-14 08	28-May-14 16	0%	35w
OCRS-I-1470	Construction - Gate House-Electrical Works	3w	29-May-14 08	16-Jun-14 16	0%	35w
OCRS-I-1480	Construction - Gate House-Mechanical Works	3w	29-May-14 08	16-Jun-14 16	0%	35w
OCRS-I-1490	Construction - Gate House-Architectural Works	1w	17-Jun-14 08	21-Jun-14 16	0%	35w
LV Refuel Facility		13w	12-May-14 08	24-Jul-14 16		29w
OCRS-I-1500	Construction - LV Refuel Facility- Surveying and detailed Earthw	0w	12-May-14 08	13-May-14 16	0%	7w
OCRS-I-1510	Construction - LV Refuel Facility- Foundation works, Ground sla	7w	14-May-14 08	26-Jun-14 16	0%	7w
OCRS-I-1520	Construction - LV Refuel Facility- Structure	2w	27-Jun-14 08	05-Jul-14 16	0%	29w
OCRS-I-1530	Construction - LV Refuel Facility- Roofing	0w	07-Jul-14 08	08-Jul-14 16	0%	29w
OCRS-I-1540	Construction - LV Refuel Facility- Mechanical Works incl. instal	2w	09-Jul-14 08	18-Jul-14 16	0%	29w
OCRS-I-1550	Construction - LV Refuel Facility- Electrical & Instrumentation	1w	19-Jul-14 08	24-Jul-14 16	0%	29w
Light Vehicle Washdown Facility		7w	27-Jun-14 08	04-Aug-14 16		26w
OCRS-I-1560	Construction - LV Washdown Facility-Surveying and detailed Ea	0w	27-Jun-14 08	28-Jun-14 16	0%	7w
OCRS-I-1570	Construction - LV Washdown Facility-Foundation works, Ground	3w	30-Jun-14 08	16-Jul-14 16	0%	7w
OCRS-I-1580	Construction - LV Washdown Facility-Structure	2w	17-Jul-14 08	25-Jul-14 16	0%	26w
OCRS-I-1590	Construction - LV Washdown Facility-Roofing & Cladding	0w	26-Jul-14 08	28-Jul-14 16	0%	26w
OCRS-I-1600	Construction - LV Washdown Facility-Connect Water Reticulati	0w	29-Jul-14 08	29-Jul-14 16	0%	26w
OCRS-I-1610	Construction - LV Washdown Facility-Electrical & Instrumentat	1w	30-Jul-14 08	04-Aug-14 16	0%	26w
Oily Water Treatment Plant & Recovery System		3w	17-Jul-14 08	31-Jul-14 16		28w
OCRS-I-1620	Construction - Oily Water Treatment Plant- Surveying, detailed E	1w	17-Jul-14 08	19-Jul-14 16	0%	7w
OCRS-I-1630	Construction - Oily Water Treatment Plant- Install inground Serv	2w	21-Jul-14 08	29-Jul-14 16	0%	28w
OCRS-I-1640	Construction - Oily Water Treatment Plant- Electrical & Instrum	0w	30-Jul-14 08	31-Jul-14 16	0%	28w
Potable/Raw/Fire Water Facility		13w	21-Jul-14 08	04-Oct-14 16		7w
OCRS-I-1650	Construction - Potable/ Raw/Fire Water Facility- Surveying and d	3w	21-Jul-14 08	06-Aug-14 16	0%	7w
OCRS-I-1660	Construction - Potable/ Raw/Fire Water Facility- Foundation worl	5w	07-Aug-14 08	04-Sep-14 16	0%	7w
OCRS-I-1670	Construction - Potable/ Raw/Fire Water Facility- Structure	1w	05-Sep-14 08	12-Sep-14 16	0%	7w
OCRS-I-1690	Construction - Potable/ Raw/Fire Water Facility- Install inground	2w	13-Sep-14 08	22-Sep-14 16	0%	7w
OCRS-I-1700	Construction - Potable/ Raw/Fire Water Facility- Electrical & Ins	2w	23-Sep-14 08	04-Oct-14 16	0%	7w
Roads, Drains, Car Parks and Finishing Works		10w	06-Oct-14 08	02-Dec-14 16		7w
OCRS-I-1710	Construction - Roads, Drainage system, Car park, Landscaping	10w	06-Oct-14 08	02-Dec-14 16	0%	7w
Process Equipment		24w	03-Oct-14 08	04-Apr-15 16		0w
OCRS-I-1800	Installation - First Portal Lathe	8w	03-Oct-14 08	20-Nov-14 16	0%	8w
OCRS-I-1810	Installation - Bogie Shop Equipment	10w	03-Oct-14 08	28-Nov-14 16	0%	4w
OCRS-I-1820	Installation - Second Portal Lathe	8w	21-Nov-14 08	09-Feb-15 16	0%	8w
OCRS-I-1830	Installation - Main Line	10w	29-Nov-14 08	04-Mar-15 16	0%	4w
OCRS-I-1840	Installation - Structural Shop	5w	29-Nov-14 08	28-Jan-15 16	0%	10w
OCRS-I-1850	Installation - AGV's	4w	29-Nov-14 08	21-Jan-15 16	0%	10w
OCRS-I-1860	Installation - Integration & Control System	10w	29-Nov-14 08	05-Mar-15 16	0%	4w
OCRS-I-1870	Installation - Wheel Shop Equipment	12w	12-Jan-15 08	04-Apr-15 16	0%	0w
Commissioning		59w	22-Jun-14 08	22-Aug-15 14		0w
Main Workshop and Other NPI		30w	22-Jun-14 08	03-Feb-15 16		9w
Main Workshop		10w	19-Sep-14 08	28-Nov-14 16		6w
62-EP-T-2930	Commissioning - Workshop Zone A (Wheelshop, Bogie shop, a	2w	19-Sep-14 08	02-Oct-14 16	0%	4w
62-EP-T-2940	Commissioning - Workshop Zone B (Admin Office, Structual shc	2w	15-Nov-14 08	28-Nov-14 16	0%	6w



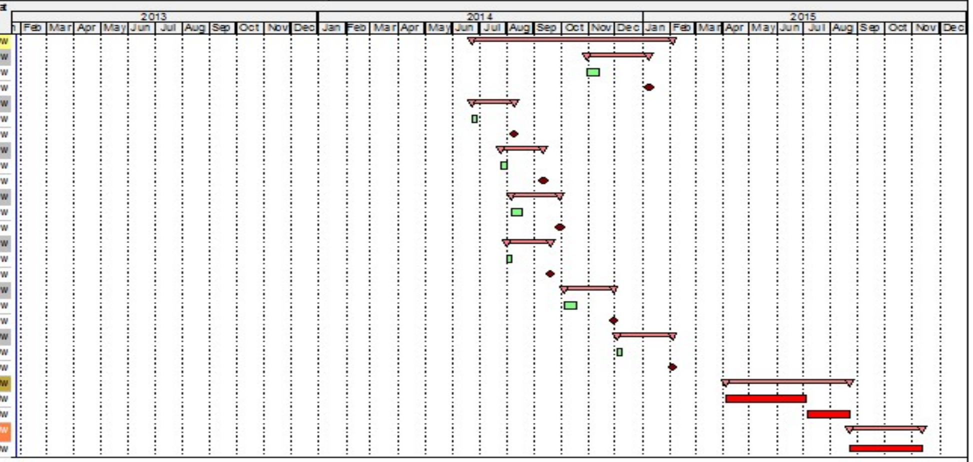
Actual Work — Critical Remaining Work — Summary
Remaining Work — Milestone

TASK filter: All Activities
Layout: OCRS

Ore Car Repair Shop Execution Schedule

Data Date: 25-Jan-13

Activity ID	Activity Name	Original Duration	Start	Finish	Activity % Complete	Total Float
Other NPI		30w	22-Jun-14 08	03-Feb-15 16		9w
Warehouse		8w	31-Oct-14 08	08-Jan-15 16		12w
62-EP-T-2950	Commissioning - Warehouse	2w	31-Oct-14 08	13-Nov-14 16	0%	12w
62-EP-T-2960	Commissioning - Warehouse Complete - FSH	0w		08-Jan-15 16	0%	12w
Gate House		7w	22-Jun-14 08	09-Aug-14 16		32w
62-EP-T-2970	Commissioning - Gate House	1w	22-Jun-14 08	28-Jun-14 16	0%	32w
62-EP-T-2980	Commissioning - Gate House Complete - FSH	0w		09-Aug-14 16	0%	32w
LV Refuel Facility		7w	25-Jul-14 08	11-Sep-14 16		27w
62-EP-T-2990	Commissioning - LV Refuel Facility	1w	25-Jul-14 08	31-Jul-14 16	0%	27w
62-EP-T-3000	Commissioning - LV Refuel Facility Complete - FSH	0w		11-Sep-14 16	0%	27w
Light Vehicle Washdown Facility		8w	05-Aug-14 08	29-Sep-14 16		25w
62-EP-T-3010	Commissioning - LV Washdown Facility	2w	05-Aug-14 08	18-Aug-14 16	0%	25w
62-EP-T-3020	Commissioning - LV Washdown Facility Complete - FSH	0w		29-Sep-14 16	0%	25w
Oily Water Treatment Plant & Recovery System		7w	01-Aug-14 08	18-Sep-14 16		26w
62-EP-T-3030	Commissioning - Oily Water Treatment Plant	1w	01-Aug-14 08	07-Aug-14 16	0%	26w
62-EP-T-3040	Commissioning - Oily Water Treatment Plant Complete - FSH	0w		18-Sep-14 16	0%	26w
Potable/Raw/Fire Water Facility		8w	05-Oct-14 08	29-Nov-14 16		16w
62-EP-T-3050	Commissioning - Potable/Raw/Fire Water Facility	2w	05-Oct-14 08	18-Oct-14 16	0%	16w
62-EP-T-3060	Commissioning - Potable/Raw/Fire Water Facility Complete - FS	0w		29-Nov-14 16	0%	16w
Roads, Drains, Car Parks and Finishing Works		7w	03-Dec-14 08	03-Feb-15 16		9w
62-EP-T-3070	Commissioning - Landscaping & Finishing works	1w	03-Dec-14 08	09-Dec-14 16	0%	9w
62-EP-T-3080	Commissioning - Landscaping & Finishing works Complete - FS	0w		03-Feb-15 16	0%	9w
Process Equipment		20w	05-Apr-15 08	22-Aug-15 14		0w
62-EP-T-2700	Commissioning - Process Equipment incl. Portal Lathes	13w	05-Apr-15 08	04-Jul-15 16	0%	0w
62-EP-T-2690	Commissioning - Overall Control System	7w	05-Jul-15 08	22-Aug-15 14	0%	0w
Operations Ramp Up		12w	22-Aug-15 14	11-Nov-15 14		0w
62-EP-R-1010	Ramp Up - Operations Ramp Up	12w	22-Aug-15 14	11-Nov-15 14	0%	0w



Actual Work
Critical Remaining Work
Summary
Remaining Work
Milestone

TASK filter: All Activities
Layout: OCRS

FIGURE 8-6 Project Master Plan

8.16. Project Critical Path

The project critical path represents the longest path through the project which determines the shortest possible project duration. All the activities in the critical path have zero free & total floats [Demeulemeester and Herroelen, 2002].

The project critical path runs through the process equipment (PE). The critical activities include engineering for tendering, tender phase, design, manufacture and delivery to site, installation, commissioning and ramp up as shown in Figure 8-7.

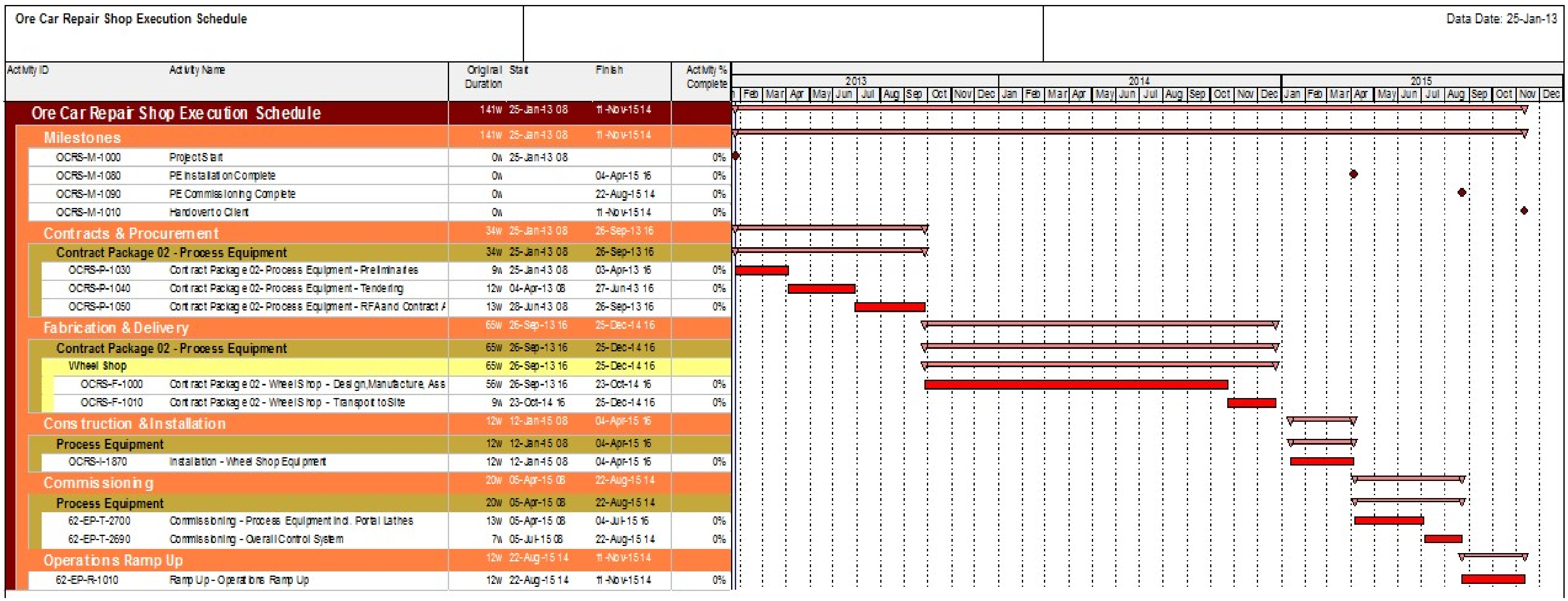
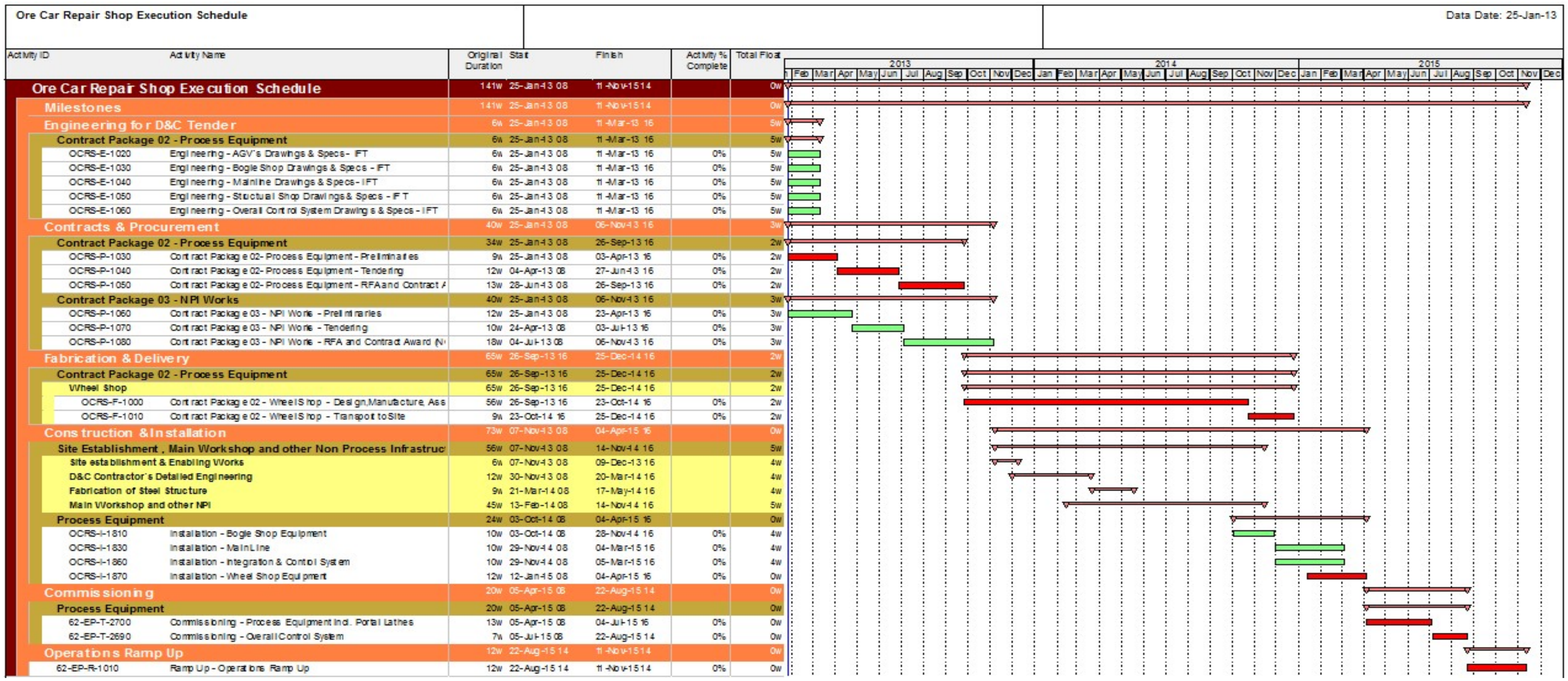


FIGURE 8-7 **Project Critical Path**

8.17. Project Near Critical Activities (Total Float < 60 days)

The project manager should focus both critical and near critical activities to minimize the risk of project delays. Figure 8-8 demonstrates filters for all activities with less than 2 months float that includes Engineering for NPI tendering, NPI tendering phase, NPI contractor site establishment & early works, engineering & fabrication of the steel structure for the workshop building, construction of the workshop, and installation of PE.



Activity ID	Activity Name	Original Duration	Start	Finish	Activity % Complete	Total Float
	Ore Car Repair Shop Execution Schedule	141w	25-Jan-13 08	11-Nov-15 14		0w
	Milestones	141w	25-Jan-13 08	11-Nov-15 14		0w
	Engineering for D&C Tender	6w	25-Jan-13 08	11-Mar-13 16		5w
	Contract Package 02 - Process Equipment	6w	25-Jan-13 08	11-Mar-13 16		5w
OCRS-E-1020	Engineering - AGV's Drawings & Specs - IFT	6w	25-Jan-13 08	11-Mar-13 16	0%	5w
OCRS-E-1030	Engineering - Bogie Shop Drawings & Specs - IFT	6w	25-Jan-13 08	11-Mar-13 16	0%	5w
OCRS-E-1040	Engineering - Mainline Drawings & Specs - IFT	6w	25-Jan-13 08	11-Mar-13 16	0%	5w
OCRS-E-1050	Engineering - Stuctual Shop Drawings & Specs - IFT	6w	25-Jan-13 08	11-Mar-13 16	0%	5w
OCRS-E-1060	Engineering - Overall Control System Drawings & Specs - IFT	6w	25-Jan-13 08	11-Mar-13 16	0%	5w
	Contracts & Procurement	40w	25-Jan-13 08	06-Nov-13 16		3w
	Contract Package 02 - Process Equipment	34w	25-Jan-13 08	26-Sep-13 16		2w
OCRS-P-1030	Contract Package 02- Process Equipment - Preliminaries	9w	25-Jan-13 08	03-Apr-13 16	0%	2w
OCRS-P-1040	Contract Package 02- Process Equipment - Tendering	12w	04-Apr-13 08	27-Jun-13 16	0%	2w
OCRS-P-1050	Contract Package 02- Process Equipment - RFA and Contract A	13w	28-Jun-13 08	26-Sep-13 16	0%	2w
	Contract Package 03 - NPI Works	40w	25-Jan-13 08	06-Nov-13 16		3w
OCRS-P-1060	Contract Package 03 - NPI Works - Preliminaries	12w	25-Jan-13 08	23-Apr-13 16	0%	3w
OCRS-P-1070	Contract Package 03 - NPI Works - Tendering	10w	24-Apr-13 08	03-Jul-13 16	0%	3w
OCRS-P-1080	Contract Package 03 - NPI Works - RFA and Contract Award (N	18w	04-Jul-13 08	06-Nov-13 16	0%	3w
	Fabrication & Delivery	65w	26-Sep-13 16	25-Dec-14 16		2w
	Contract Package 02 - Process Equipment	65w	26-Sep-13 16	25-Dec-14 16		2w
	Wheel Shop	65w	26-Sep-13 16	25-Dec-14 16		2w
OCRS-F-1000	Contract Package 02 - Wheel Shop - Design,Manufacture, Ass	56w	26-Sep-13 16	23-Oct-14 16	0%	2w
OCRS-F-1010	Contract Package 02 - Wheel Shop - Transport to Site	9w	23-Oct-14 16	25-Dec-14 16	0%	2w
	Construction & Installation	73w	07-Nov-13 08	04-Apr-15 16		0w
	Site Establishment , Main Workshop and other Non Process Infrastruc	56w	07-Nov-13 08	14-Nov-14 16		5w
	Site establishment & Enabling Works	6w	07-Nov-13 08	09-Dec-13 16		4w
	D&C Contractor's Detailed Engineering	12w	30-Nov-13 08	20-Mar-14 16		4w
	Fabrication of Steel Structure	9w	21-Mar-14 08	17-May-14 16		4w
	Main Workshop and other NPI	45w	13-Feb-14 08	14-Nov-14 16		5w
	Process Equipment	24w	03-Oct-14 08	04-Apr-15 16		0w
OCRS-I-1810	Installation - Bogie Shop Equipment	10w	03-Oct-14 08	28-Nov-14 16	0%	4w
OCRS-I-1830	Installation - Main Line	10w	29-Nov-14 08	04-Mar-15 16	0%	4w
OCRS-I-1860	Installation - Integration & Control System	10w	29-Nov-14 08	05-Mar-15 16	0%	4w
OCRS-I-1870	Installation - Wheel Shop Equipment	12w	12-Jan-15 08	04-Apr-15 16	0%	0w
	Commissioning	20w	05-Apr-15 08	22-Aug-15 14		0w
	Process Equipment	20w	05-Apr-15 08	22-Aug-15 14		0w
62-EP-T-2700	Commissioning - Process Equipment Incl. Portal Lathes	13w	05-Apr-15 08	04-Jul-15 16	0%	0w
62-EP-T-2690	Commissioning - Overall Control System	7w	05-Jul-15 08	22-Aug-15 14	0%	0w
	Operations Ramp Up	12w	22-Aug-15 14	11-Nov-15 14		0w
62-EP-R-1010	Ramp Up - Operations Ramp Up	12w	22-Aug-15 14	11-Nov-15 14	0%	0w

FIGURE 8-8 **Project Near Critical Tasks**

8.18. Quantity Profile & Commodity Rundown Curves

An initial resource profile has been generated for NPI and PE packages based on approved quantity estimates. The table detailing the quantity loading by commodity type is shown in Table 8-28, related histogram and rundown curves are as per Figures 8-9 and 8-10.

Table 8-28 Project Quantity Usage

Quantity Loading by Commodity																		
Resource ID	Resource Name	UoM	Budgeted Unit	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15
Material																		
Q0	Earthworks & Civil	M3	53,592	2,059	4,891	3,358	19	149	23	11	-	19,818	21,541	1,723	-	-	-	-
Q1	Concrete	M3	5,400	-	-	660	2,076	1,305	222	12	1,050	75	-	-	-	-	-	-
Q2	Structural Steel	Ton	830	-	-	-	160	240	261	162	7	-	-	-	-	-	-	-
Q3	Architectural	M2	13,372	-	-	-	-	3,492	3,371	3,312	2,634	563	-	-	-	-	-	-
Q6	Piping	M	5,581	352	811	272	14	56	467	1,146	1,132	931	400	-	-	-	-	-
Q7	Electrical	M	67,860	420	970	930	1,249	160	5,439	17,303	15,518	17,794	7,972	105	-	-	-	-
Q8	Control System	M	17,672	1,229	2,835	950	-	-	1,065	3,273	2,782	4,593	945	-	-	-	-	-

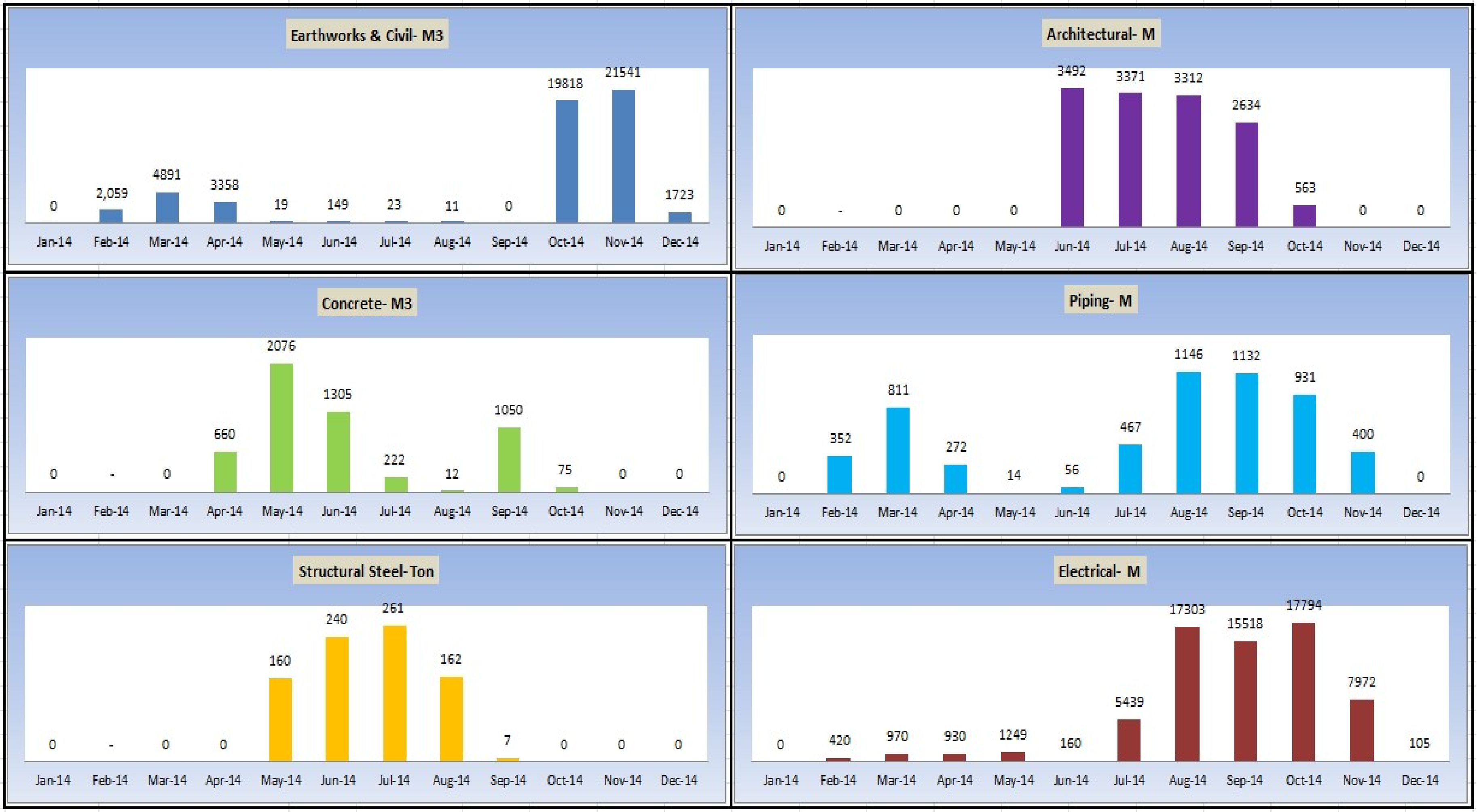


FIGURE 8-9 **Project Quantity Usage Profile**

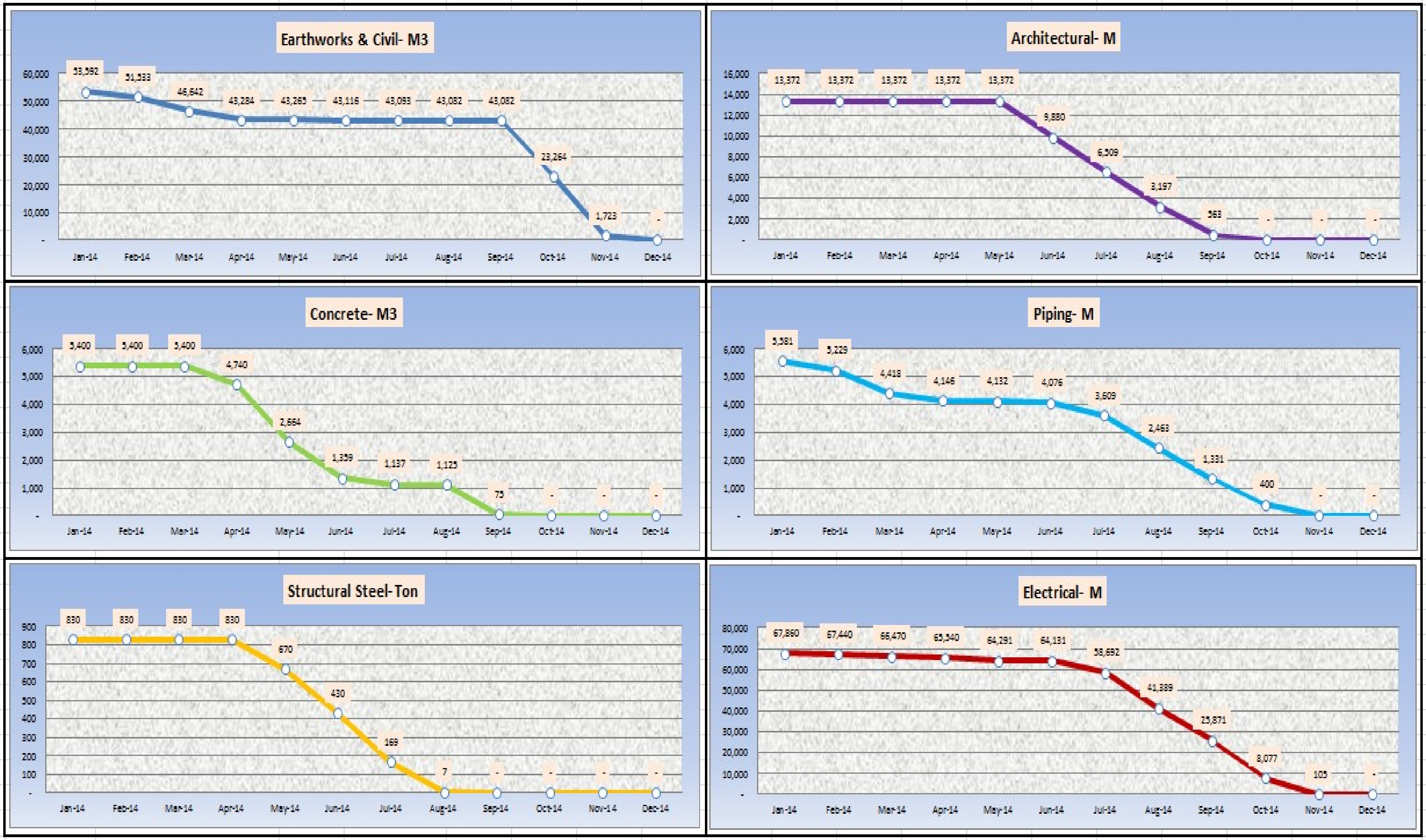


FIGURE 8-10 **Project Commodity Rundown Curve**

- **Manning Profile**

Man-hours required for project have been loaded into the schedule and the outcome would be budgeted hour per period and manning histogram. Table 8-29 demonstrates man-hour usage per month and Figure 8-11 shows required NPI & PE workforces at construction and commissioning phases.

TABLE 8-29 Project Manning Profile

Man-Hours Loading by Commodity																		
Resource ID	Resource Name	UoM	Budgeted Unit	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15
Man-Hours																		
A0	Earthworks & Civil	Hrs	15,426	933	2,298	2,236	7	11	5	3	-	4,569	4,967	397	-	-	-	-
A1	Concrete	Hrs	47,071	-	-	5,082	17,298	11,795	2,070	159	9,958	709	-	-	-	-	-	-
A2	Structural Steel	Hrs	37,392	-	-	-	6,547	9,789	11,247	9,320	489	-	-	-	-	-	-	-
A3	Architectural	Hrs	19,271	-	-	-	-	3,122	3,202	5,742	4,988	1,981	236	-	-	-	-	-
A5	Machinery & Equipment	Hrs	46,506	-	-	-	20	80	549	404	1,532	6,701	6,354	5,025	8,886	9,316	6,542	1,097
A6	Piping	Hrs	5,123	132	305	102	6	23	453	1,364	1,270	1,021	447	-	-	-	-	-
A7	Electrical	Hrs	27,248	395	912	875	1,145	30	1,759	5,902	5,398	7,059	3,674	99	-	-	-	-
A8	Control Systems	Hrs	7,538	184	424	142	-	-	322	671	904	1,835	656	576	672	960	192	-
	Subtotal		205,575	1,644	3,939	8,437	25,023	24,850	19,607	23,565	24,539	23,875	16,334	6,097	9,558	10,276	6,734	1,097

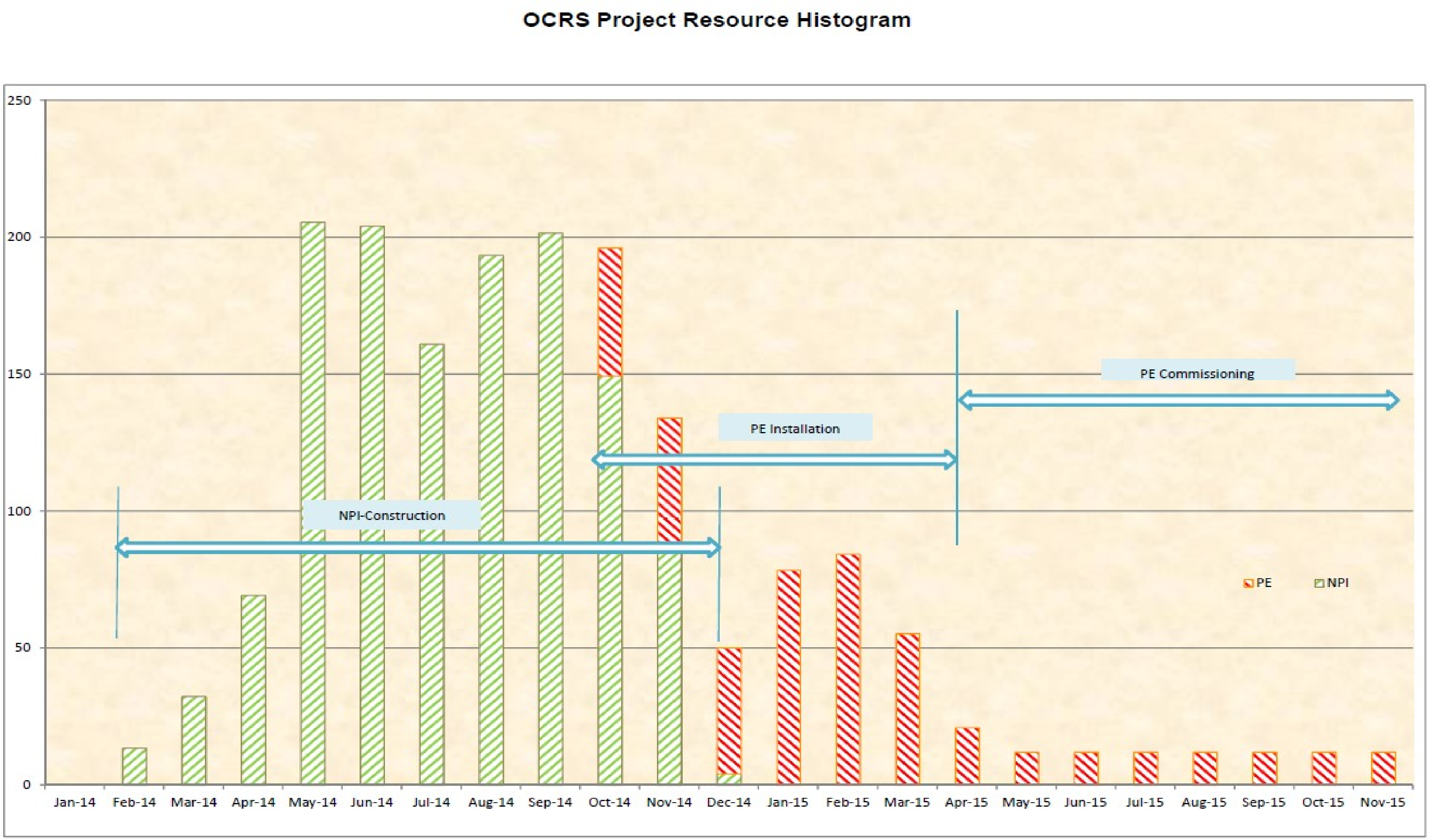


FIGURE 8-11 Project Resource Histogram

8.19. Progress Early & Late Curves

Man-hours allocated to the construction and commissioning activities are used as a basis of progress curve development. All required man-hours are directly tied to the schedule activities which enables a time-phased view of the hour's baseline (typically displayed in the form of an S-curve).

The ratio of the required hours for the period to the total baseline hours will form progress S-curve on a cumulative basis. Planned S-curves can be generated based on the activities` early and late dates (called a "banana curve") [Ishtiag,M, 2016]. Figure 8-12 illustrates OCRS construction & installation "Banana" curves.

Description - Progress		2014												2015				
		Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15
EARLY PLAN	This Period		0.8%	1.9%	4.1%	12.2%	12.1%	9.5%	11.5%	11.9%	11.6%	7.9%	3.0%	4.6%	5.0%	3.3%	0.5%	
	Cumulative		0.8%	2.7%	6.8%	19.0%	31.1%	40.6%	52.1%	64.0%	75.6%	83.6%	86.5%	91.2%	96.2%	99.5%	100.0%	
LATE PLAN	This Period			0.7%	1.8%	3.6%	9.3%	12.8%	9.3%	10.7%	11.1%	9.7%	8.6%	4.4%	7.0%	9.2%	1.7%	
	Cumulative			0.7%	2.5%	6.0%	15.3%	28.2%	37.5%	48.2%	59.3%	69.1%	77.6%	82.0%	89.0%	98.3%	100.0%	

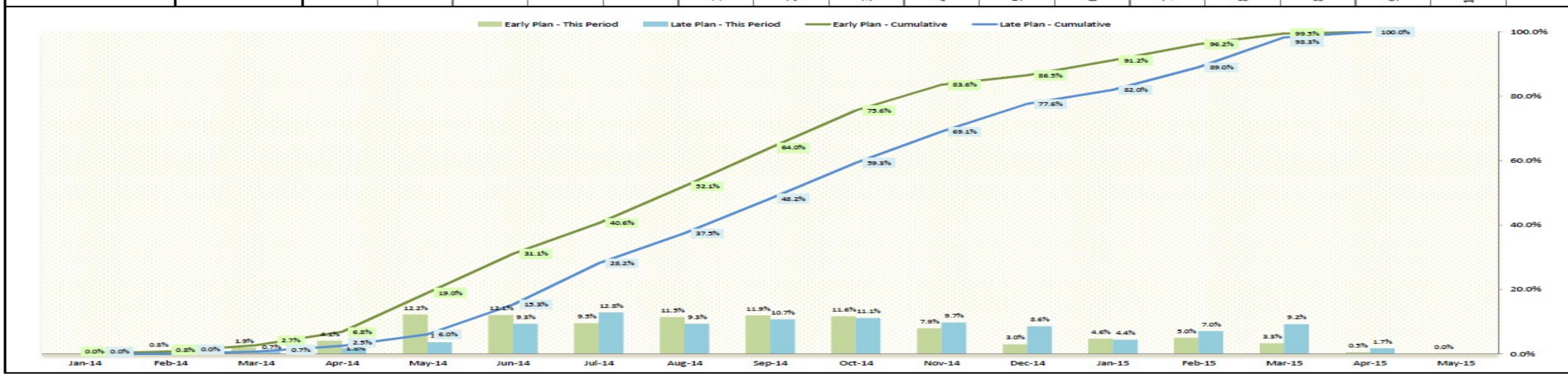


FIGURE 8-12 Project Progress Curve

8.20. Project Time and Cost trade-off

In a typical construction project, activity durations vary depending on amount and type of resources that are applied. It is important to plan the construction activities to conclude at a predefined deadline. The objective of the time-cost trade-off is to reduce project duration with minimum cost to improve project cash flow, to receive an early completion bonus or to recover project delays. This can be achieved by applying multiple-shifts work, working overtime, working weekends & holidays, using better construction methods, using additional resources, offering bonus to increase productivity, and using materials & equipment with expedited schedules.

Shortening the duration on an activity will generally increase its direct cost and in the critical path will decrease the project duration and subsequent indirect costs. A cost slope and simple representation of cost & time relationship for each activity can be defined in Figure 8-13 [E. Elbeltagi,2009].

$$\text{Cost Slope} = \frac{(\text{Crash Cost} - \text{Normal Cost})}{(\text{Normal Duration} - \text{Crash Duration})}$$

EQUATION 8-1 **Cost Slope**

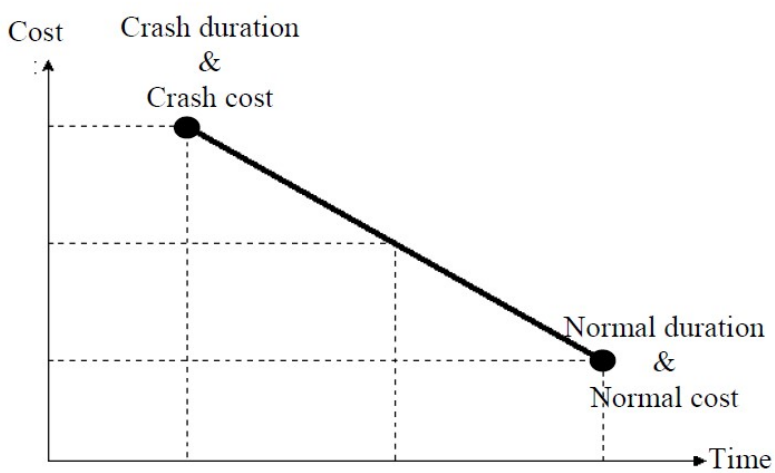


FIGURE 8-13 **Cost Slope**

Project indirect costs are usually indirectly related to the project duration. Figure 8-14 defines the direct and indirect relationships with the project duration. The optimum project duration can be determined on the date resulting in the least project total cost.

The cost/slope method is used to identify project optimum duration. This method shortens critical activities with the lowest cost slopes until the crash duration is reached or until the critical path varies. The direct cost increase due to activity shortening is calculated as the cost slope is multiplied by the time of units shortened.

The results may be represented graphically by plotting project completion time against cumulative cost increase. Adding the project indirect cost to this curve gives the optimum duration and corresponding minimum cost [E. Elbeltagi,2009].

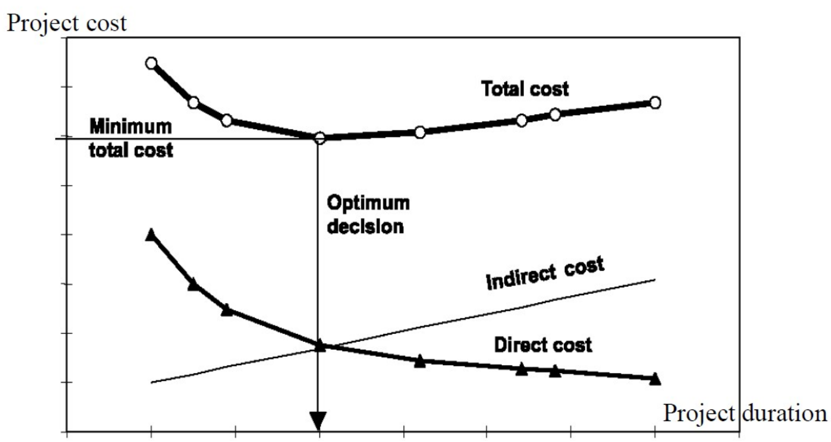


FIGURE 8-14 Direct & Indirect Costs Curves

Below is the calculation of OCRS optimum duration and amount of savings by crashing the project critical path:

Note: As project financial data is confidential, our practice would be based on direct man-hours required for project`s fabrication, construction, installation, commissioning, and ramp up. EPCM engineering services are not included in this estimate.

- **Project Critical & Near Critical path**

As outlined in section 8.16 and 8.17, PE package – Wheel shop from tendering phase to commissioning & ramp up are on the critical path. Therefore, crashing will commence through these activities with least costs.

Near critical activities run through the NPI package. This includes NPI tendering processes, early works and site establishment and construction & commissioning of the main workshop building. As shown in Figure 8-15 completion of the main workshop building can be postponed 41 days before installation of PE-Wheel shop starts (Total Float: 41 days). This path cannot be considered for crashing until the project critical path (PE package) is shortened over 41 days.

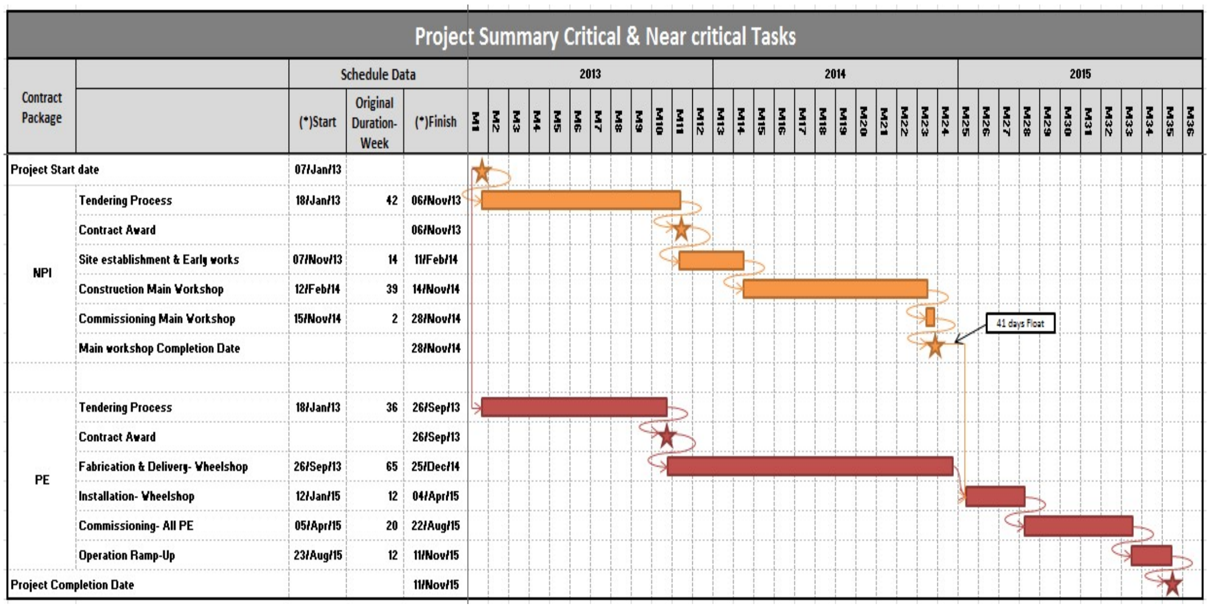


FIGURE 8-15 **Project Critical & Near Critical Summary Tasks**

➢ **Project Direct hours estimates**

Refer to project estimates, required direct hours for construction & installation phases were estimated 205,575 hrs. In addition, direct hours for Fabrication & Deliveries, Commissioning, and ramp up phases are shown in Table 8-30:

TABLE 8-30 Project Direct Man Hours

OCRS Project required Direct Man-Hours								
Category	**Area**	**Engineering**	**Fabrication & Delivery**	**Construction**	**Installation**	**Commissioning**	**Ramp up**	**Total Direct Hours**
PL	Portal Lathes	N/A	47,120		6,409			
	AGV`s		31,200		1,915			
	BOGIE SHOP		26,000		7,319			
PE	MAINLINE	N/A	28,000		8,459	20,160	12,096	*274,859*
	WHEELSHOP		31,360		16,465			
	STRUCTURAL SHOP		12,000		1,864			
	OVERALL CONTROL SYSTEM		22,000		2,493			
	LV REFUEL FACILITY		0	1,330				*1,330*
	OILY WATER TREATMENT		0	175				*175*
	GATEHOUSE		0	823				*823*
NPI	POTABLE/RAW/FIRE WATER FACILITY	N/A	0	1,576				*1,576*
	SITE WIDE EARTHWORK/CIVIL & SITEWIDE SERVICEs		0	20,855				*20,855*
	WAREHOUSE		0	14,060				*14,060*
	WORKSHOP		0	106,690				*106,690*
	WORKSHOP OFFICE		0	13,776				*13,776*
	Grand Total	N/A	197,680	160,651	44,923	20,160	12,096	*435,511*
* EPCM Engineering efforts not included in project estimates				205,575				
* NPI commissioning Hours are considered in Construction Hours								
* Only highlighted items (Critical & near critical activities) will be selected for Crashing								

➢ **Man-hours estimates for Critical & Near critical activities**

To crash project duration and to determine optimum point, only critical & near critical activities are selected with Table 8-31 summarising the related direct hours.

TABLE 8-31 Project Crashing Data

OCRS project Cost & Time Trade off							
Contract Package	Activity Description	Original Schedule data				Crash data	
		(*)Start	Duration	(*)Finish	Required Manhours	Crash Duration	Crash Man-hours
Project Start date		07/Jan/13					
NPI	Tendering Process	18/Jan/13	293	06/Nov/13	-	293	-
NPI	Contract Award	06/Nov/13	-	06/Nov/13	-	-	-
NPI	Site establishment & Early works	07/Nov/13	97	11/Feb/14	20,855	80	23,450
NPI	Construction Main Workshop	12/Feb/14	276	14/Nov/14	104,812	215	117,380
NPI	Commissioning Main Workshop	15/Nov/14	14	28/Nov/14	1,878	10	2,000
NPI	Main workshop Completion Date	28/Nov/14		28/Nov/14	-	-	
PE	Tendering Process	18/Jan/13	252	26/Sep/13	-	252	-
PE	Contract Award	26/Sep/13		26/Sep/13	-	-	
PE	Fabrication & Delivery- Wheelshop	26/Sep/13	456	25/Dec/14	31,360	380	39,500
PE	Installation- Wheelshop	26/Dec/14	100	04/Apr/15	16,465	70	19,300
PE	Installation- All PE Exclude Wheelshop	03/Aug/14	216	06/Mar/15	28,459	170	32,540
PE	Commissioning- All PE	05/Apr/15	140	22/Aug/15	20,160	110	22,850
PE	Operation Ramp-Up	23/Aug/15	81	11/Nov/15	12,096	70	12,990
Project Completion Date		11/Nov/15		11/Nov/15			

- **Indirect Man-Hours**

Project indirect hours during construction, installation, commissioning, and ramp up phases are estimated as per Table 8-32.

TABLE 8-32 Project Indirect Estimates

Project Indirect hours estimate per day				
Id	Indirects	No. of Res	Working Hrs / day	Total Man-Hours / day
1	Project Management team- Office	5	8	40
2	Superintendents- Site	2	12	24
3	Supervisors- Site	4	12	48
4	Other indirects- Site	12	12	144
				256

According to project schedule, the construction phase is planned to start on 07 November 13. Subsequently, 734 days are required to complete the project scope on client requested target date (11 Nov 15).

Project duration: 734 days

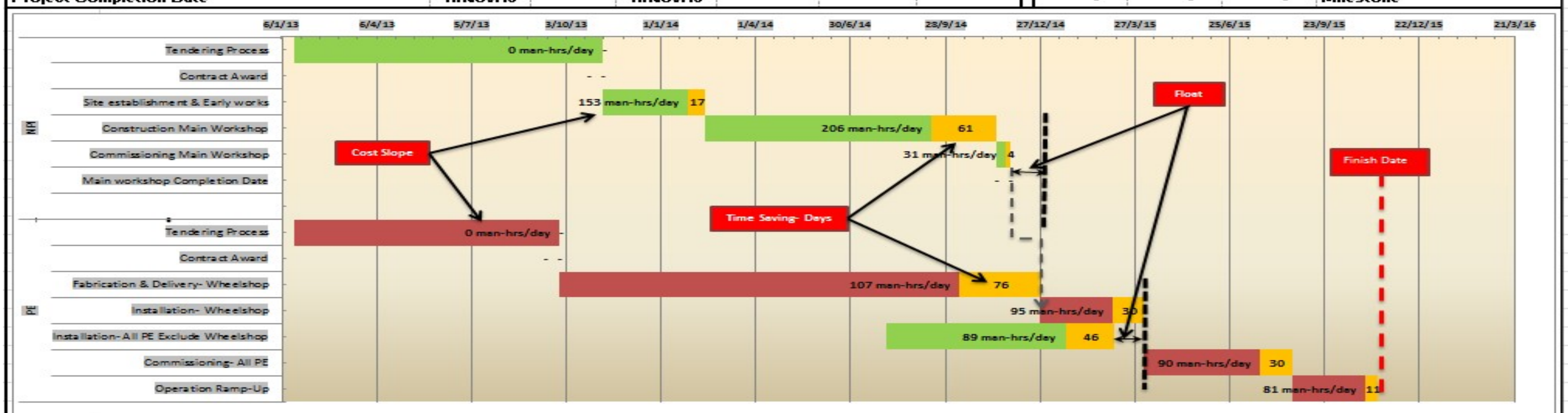
Indirect man-hours per day: 256 hrs/day

Total required indirect hours as of construction start date = 734 days * 256 hrs/day = 187,904

- **Crashing Process:**
    - Schedule critical & near critical tasks, baseline data, crashing data, and fenced-bar chart are developed as shown in Table 8-33.

TABLE 8-33 Crashing Data

OCRS project Cost & Time Trade off												
Contract Package	Activity Description	Original Schedule data				Crash data		Time Saving-Days	Extra required Man-Hours	Extra required Man-Hours per day	Comments
		(*)Start	Duration	(*)Finish	Required Manhours	Crash Duration	Crash Man-hours				
Project Start date		07/Jan/13									
NPI	A Tendering Process	18/Jan/13	293	06/Nov/13	-	293	-	-	-	-	EPCM services not included
	B Contract Award	06/Nov/13	-	06/Nov/13	-	-	-	-	-	-	Milestone
	C Site establishment & Early works	07/Nov/13	97	11/Feb/14	20,855	80	23,450	17	2,595	153	
	D Construction Main Workshop	12/Feb/14	276	14/Nov/14	104,812	215	117,380	61	12,568	206	
	E Commissioning Main Workshop	15/Nov/14	14	28/Nov/14	1,878	10	2,000	4	122	31	
	F Main workshop Completion Date	28/Nov/14		28/Nov/14	-	-		-	-	-	Milestone
PE	G Tendering Process	18/Jan/13	252	26/Sep/13	-	252	-	-	-	-	EPCM services not included
	H Contract Award	26/Sep/13		26/Sep/13	-	-		-	-	-	Milestone
	I Fabrication & Delivery- Wheelshop	26/Sep/13	456	25/Dec/14	31,360	380	39,500	76	8,140	107	Data quoted from supplier
	J Installation- Wheelshop	26/Dec/14	100	04/Apr/15	16,465	70	19,300	30	2,835	95	
	K Installation- All PE Exclude Wheelshop	03/Aug/14	216	06/Mar/15	28,459	170	32,540	46	4,081	89	
	L Commissioning- All PE	05/Apr/15	140	22/Aug/15	20,160	110	22,850	30	2,690	90	
	M Operation Ramp-Up	23/Aug/15	81	11/Nov/15	12,096	70	12,990	11	894	81	
Project Completion Date		11/Nov/15		11/Nov/15				-	-	-	Milestone



(dark red)	Critical Tasks- Crashed duration
(green)	Near Critical tasks- Crashed duration
(yellow)	Time savings- Days

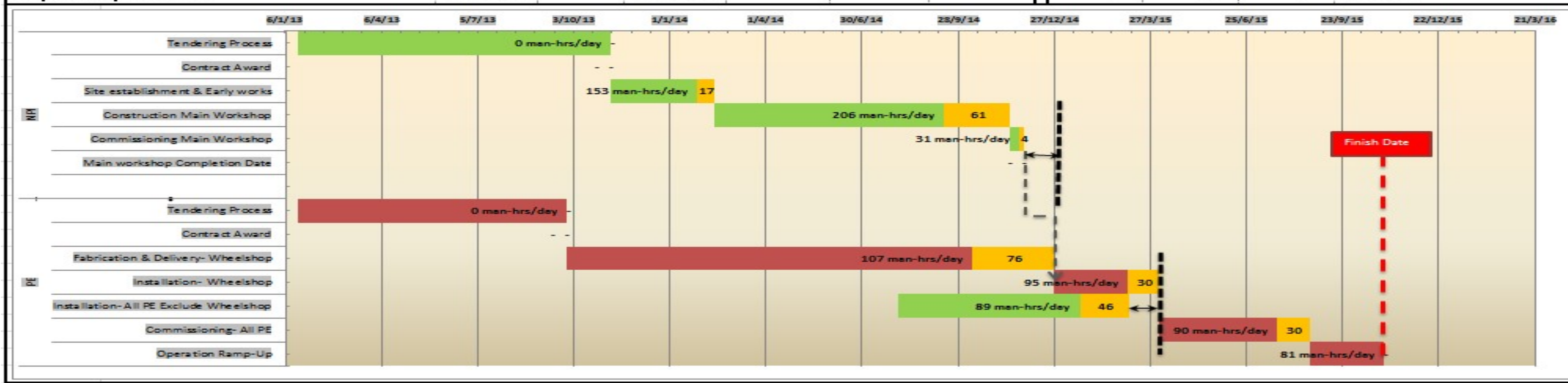
- **Crash “Operation Ramp- Up”:**

Operation ramp up is on the critical path with minimum cost slope (81 hrs/day) that can be crashed in 11 days.

New forecast finish date: 31 Oct 15 and additional direct man-hours: 81 hrs/day * 11 days ~ 894 hrs

TABLE 8-34 Crashing- Activity M

OCRS project Cost & Time Trade off													
Contract Package		Activity Description	Original Schedule data				Crash data		Time Saving- Days	Extra required Man-Hours	Extra required Man-Hours per day	Comments
			(*)Start	Duration	(*)Finish	Required Manhours	Crash Duration	Crash Man-hours				
Project Start date			07/Jan/13									
NPI	A	Tendering Process	18/Jan/13	293	06/Nov/13	-	293	-	-	-	-	EPCM services not included
	B	Contract Award	06/Nov/13	-	06/Nov/13	-	-	-	-	-	-	Milestone
	C	Site establishment & Early works	07/Nov/13	97	11/Feb/14	20,855	80	23,450	17	2,595	153	
	D	Construction Main Workshop	12/Feb/14	276	14/Nov/14	104,812	215	117,380	61	12,568	206	
	E	Commissioning Main Workshop	15/Nov/14	14	28/Nov/14	1,878	10	2,000	4	122	31	
	F	Main workshop Completion Date	28/Nov/14		28/Nov/14	-	-		-	-	-	Milestone
PE	G	Tendering Process	18/Jan/13	252	26/Sep/13	-	252	-	-	-	-	EPCM services not included
	H	Contract Award	26/Sep/13		26/Sep/13	-	-		-	-	-	Milestone
	I	Fabrication & Delivery- Wheelshop	26/Sep/13	456	25/Dec/14	31,360	380	39,500	76	8,140	107	Data quoted from supplier
	J	Installation- Wheelshop	26/Dec/14	100	04/Apr/15	16,465	70	19,300	30	2,835	95	
	K	Installation- All PE Exclude Wheelshop	03/Aug/14	216	06/Mar/15	28,459	170	32,540	46	4,081	89	
	L	Commissioning- All PE	05/Apr/15	140	22/Aug/15	20,160	110	22,850	30	2,690	90	
	M	~~Operation Ramp Up~~	~~23/Aug/15~~	~~70~~	~~31/Oct/15~~	~~12,096~~	~~70~~	~~12,990~~		~~894~~	~~Crashed~~	
Project Completion Date			31/Oct/15		31/Oct/15				-	-	-	Milestone



- **Crash “Commissioning all PE”:**

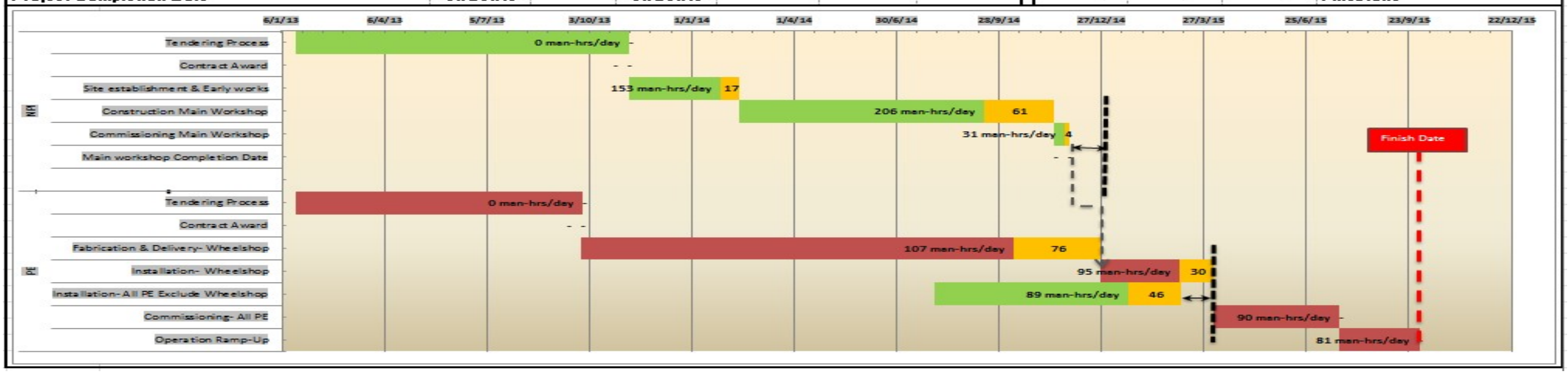
After operation ramp up, “Commissioning PE” will be selected in the critical path with minimum cost slope (90 hrs/day) that can be crashed in 30 days.

New forecast finish date: 01 Oct 15 and additional direct man-hours: 90 hrs/day * 30days ~ 2,700 hrs

TABLE 8-35 Crashing- Activity L

OCRS project Cost & Time Trade off

Contract Package		Activity Description	Original Schedule data				Crash data		Time Saving-Days	Extra required Man-Hours	Extra required Man-Hours per day	Comments
			(*)Start	Duration	(*)Finish	Required Manhours	Crash Duration	Crash Man-hours				
Project Start date			07/Jan/13									
NPI	A	Tendering Process	18/Jan/13	293	06/Nov/13	-	293	-	-	-	-	EPCM services not included
	B	Contract Award	06/Nov/13	-	06/Nov/13	-	-	-	-	-	-	Milestone
	C	Site establishment & Early works	07/Nov/13	97	11/Feb/14	20,855	80	23,450	17	2,595	153	
	D	Construction Main Workshop	12/Feb/14	276	14/Nov/14	104,812	215	117,380	61	12,568	206	
	E	Commissioning Main Workshop	15/Nov/14	14	28/Nov/14	1,878	10	2,000	4	122	31	
	F	Main workshop Completion Date	28/Nov/14		28/Nov/14	-	-		-	-	-	Milestone
PE	G	Tendering Process	18/Jan/13	252	26/Sep/13	-	252	-	-	-	-	EPCM services not included
	H	Contract Award	26/Sep/13		26/Sep/13	-	-		-	-	-	Milestone
	I	Fabrication & Delivery- Wheelshop	26/Sep/13	456	25/Dec/14	31,360	380	39,500	76	8,140	107	Data quoted from supplier
	J	Installation- Wheelshop	26/Dec/14	100	04/Apr/15	16,465	70	19,300	30	2,835	95	
	K	Installation- All PE Exclude Wheelshop	03/Aug/14	216	06/Mar/15	28,459	170	32,540	46	4,081	89	
	L	~~Commissioning- All PE~~	~~05/Apr/15~~	~~110~~	~~23/Jul/15~~	~~20,160~~	~~110~~	~~22,850~~		~~2,690~~	~~Crashed~~	
	M	~~Operation Ramp-Up~~	~~24/Jul/15~~	~~70~~	~~01/Oct/15~~	~~12,096~~	~~70~~	~~12,990~~		~~894~~	~~Crashed~~	
Project Completion Date			01/Oct/15		01/Oct/15				-	-	-	Milestone



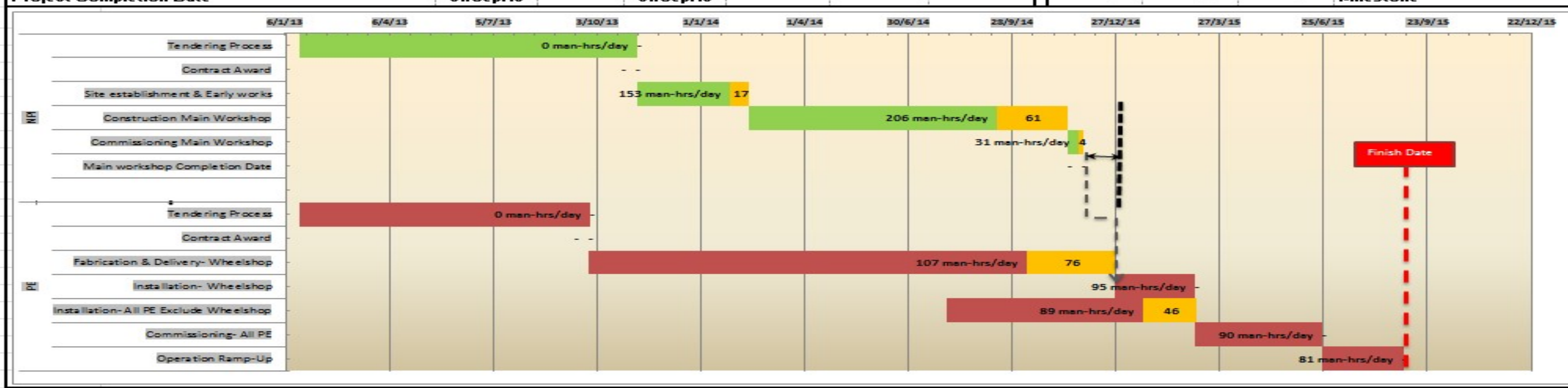
- **Crash "Installation Wheel shop":**

"Installation wheel shop" would be subsequent element on the critical path with minimum cost slope (95 hrs/day) to be crashed in 30 days.

New forecast finish date: 01 Sep 15 and additional direct man-hours: 95 hrs/day * 30days = 2,835 hrs

TABLE 8-36 Crashing- Activity J

OCRS project Cost & Time Trade off													
Contract Package		Activity Description	Original Schedule data				Crash data		Time Saving- Days	Extra required Man-Hours	Extra required Man-Hours per day	Comments
			(*)Start	Duration	(*)Finish	Required Manhours	Crash Duration	Crash Man-hours				
Project Start date			07/Jan/13									
NPI	A	Tendering Process	18/Jan/13	293	06/Nov/13	-	293	-	-	-	-	EPCM services not included
	B	Contract Award	06/Nov/13	-	06/Nov/13	-	-	-	-	-	-	Milestone
	C	Site establishment & Early works	07/Nov/13	97	11/Feb/14	20,855	80	23,450	17	2,595	153	
	D	Construction Main Workshop	12/Feb/14	276	14/Nov/14	104,812	215	117,380	61	12,568	206	
	E	Commissioning Main Workshop	15/Nov/14	14	28/Nov/14	1,878	10	2,000	4	122	31	
	F	Main workshop Completion Date	28/Nov/14		28/Nov/14	-	-		-	-	-	Milestone
PE	G	Tendering Process	18/Jan/13	252	26/Sep/13	-	252	-	-	-	-	EPCM services not included
	H	Contract Award	26/Sep/13		26/Sep/13	-	-		-	-	-	Milestone
	I	Fabrication & Delivery- Wheelshop	26/Sep/13	456	25/Dec/14	31,360	380	39,500	76	8,140	107	Data quoted from supplier
	J	~~Installation- Wheelshop~~	~~26/Dec/14~~	~~70~~	~~05/Mar/15~~	~~16,465~~	~~70~~	~~19,300~~		~~2,835~~	~~Crashed~~	
	K	Installation- All PE Exclude Wheelshop	03/Aug/14	216	06/Mar/15	28,459	170	32,540	46	4,081	89	
	L	~~Commissioning- All PE~~	~~06/Mar/15~~	~~110~~	~~23/Jun/15~~	~~20,160~~	~~110~~	~~22,850~~		~~2,690~~	~~Crashed~~	
	M	~~Operation Ramp-Up~~	~~24/Jun/15~~	~~70~~	~~01/Sep/15~~	~~12,096~~	~~70~~	~~12,990~~		~~894~~	~~Crashed~~	
Project Completion Date			01/Sep/15		01/Sep/15				-	-	-	Milestone



- **Crash a portion of “Fabrication & Delivery Wheel shop” duration and “Installation all PE excluding Wheel shop”:**

Project duration cannot be shortened if only “installation PE” is selected to crash. Both “Fabrication & Delivery Wheel shop” and “Installation all PE excluding Wheel shop” are on the critical path with minimum cost slope that can be partially crashed in 27 days. Consequently, all NPI- workshop building is effectively on the critical path.

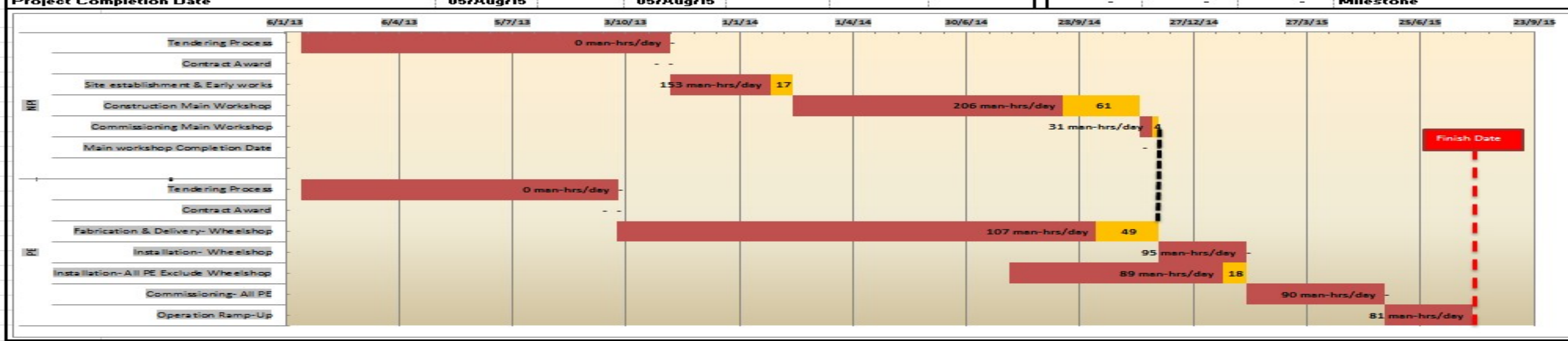
New forecast finish date: 05 Aug 15 and additional direct man-hours: (107 hrs/day * 27 days) + (89 hrs/day * 27 days) = 5,292 hrs

TABLE 8-37 Crashing- Activity I+K

OCRS project Cost & Time Trade off

Contract Package	Activity Description	Original Schedule data				Crash data	
		(*)Start	Duration	(*)Finish	Required Manhours	Crash Duration	Crash Man-hours
Project Start date		07/Jan/13					
NPI	A Tendering Process	18/Jan/13	293	06/Nov/13	-	293	-
NPI	B Contract Award	06/Nov/13	-	06/Nov/13	-	-	-
NPI	C Site establishment & Early works	07/Nov/13	97	11/Feb/14	20,855	80	23,450
NPI	D Construction Main Workshop	12/Feb/14	276	14/Nov/14	104,812	215	117,380
NPI	E Commissioning Main Workshop	15/Nov/14	14	28/Nov/14	1,878	10	2,000
NPI	F Main workshop Completion Date	28/Nov/14		28/Nov/14	-	-	
PE	G Tendering Process	18/Jan/13	252	26/Sep/13	-	252	-
PE	H Contract Award	26/Sep/13		26/Sep/13	-	-	
PE	I Fabrication & Delivery- Wheelshop	26/Sep/13	429	28/Nov/14	31,360	380	39,500
PE	J ~~Installation- Wheelshop~~	~~29/Nov/14~~	~~70~~	~~06/Feb/15~~	~~16,465~~	~~70~~	~~19,300~~
PE	K Installation- All PE Exclude Wheelshop	03/Aug/14	188	06/Feb/15	28,459	170	32,540
PE	L ~~Commissioning- All PE~~	~~07/Feb/15~~	~~110~~	~~27/May/15~~	~~20,160~~	~~110~~	~~22,850~~
PE	M ~~Operation Ramp-Up~~	~~28/May/15~~	~~70~~	~~05/Aug/15~~	~~12,096~~	~~70~~	~~12,990~~
Project Completion Date		05/Aug/15		05/Aug/15			

Contract Package	Activity Description	Time Saving-Days	Extra required Man-Hours	Extra required Man-Hours per day	Comments
Project Start date					
NPI	A Tendering Process	-	-	-	EPCM services not included
NPI	B Contract Award	-	-	-	Milestone
NPI	C Site establishment & Early works	17	2,595	153	
NPI	D Construction Main Workshop	61	12,568	206	
NPI	E Commissioning Main Workshop	4	122	31	
NPI	F Main workshop Completion Date	-	-	-	Milestone
PE	G Tendering Process	-	-	-	EPCM services not included
PE	H Contract Award	-	-	-	Milestone
PE	I Fabrication & Delivery- Wheelshop	49	8,140	107	Data quoted from supplier
PE	J ~~Installation- Wheelshop~~		~~2,835~~	~~Crashed~~	
PE	K Installation- All PE Exclude Wheelshop	18	4,081	89	
PE	L ~~Commissioning- All PE~~		~~2,690~~	~~Crashed~~	
PE	M ~~Operation Ramp-Up~~		~~894~~	~~Crashed~~	
Project Completion Date		-	-	-	Milestone



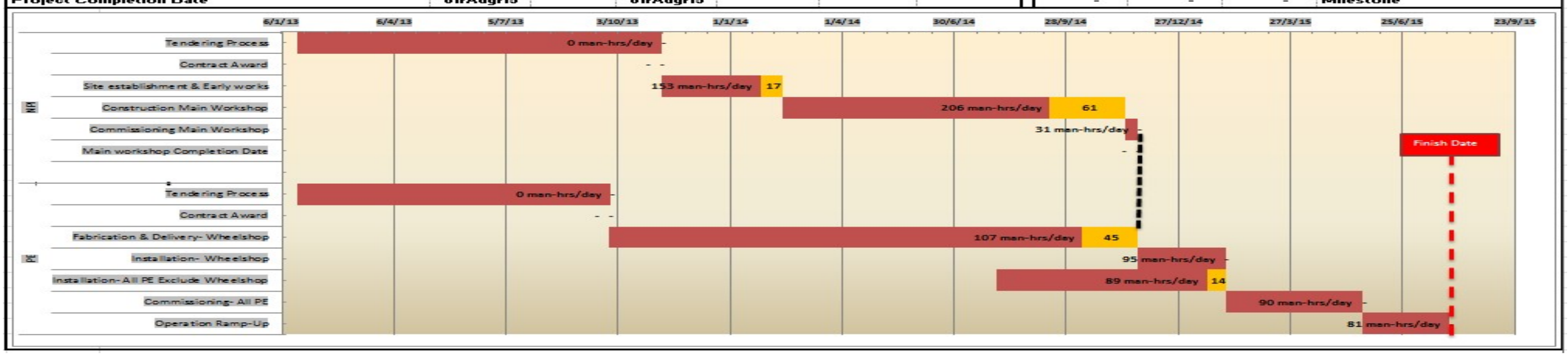
- **Crash a portion of "Fabrication & Delivery Wheel shop" duration, "NPI main workshop commissioning", and" Installation all PE":**

Both "Fabrication & Delivery-Wheel shop", "NPI main workshop commissioning" and" Installation all PE" can be crashed in 4 days.

New forecast finish date: 01 Aug 15 and additional direct man-hours: (107 hrs/day * 4 days) + (31 hrs/day * 4 days) + (89 hrs/day * 4 days) = 908 hrs

TABLE 8-38 Crashing- Activity I+K+E

OCRS project Cost & Time Trade off												
Contract Package	Activity Description	Original Schedule data				Crash data		Time Saving-Days	Extra required Man-Hours	Extra required Man-Hours per day	Comments
		(*)Start	Duration	(*)Finish	Required Manhours	Crash Duration	Crash Man-hours				
Project Start date		07/Jan/13									
NPI	A Tendering Process	18/Jan/13	293	06/Nov/13	-	293	-	-	-	-	EPCM services not included
NPI	B Contract Award	06/Nov/13	-	06/Nov/13	-	-	-	-	-	-	Milestone
NPI	C Site establishment & Early works	07/Nov/13	97	11/Feb/14	20,855	80	23,450	17	2,595	153	
NPI	D Construction Main Workshop	12/Feb/14	276	14/Nov/14	104,812	215	117,380	61	12,568	206	
NPI	~~E Commissioning Main Workshop~~	~~15/Nov/14~~	~~10~~	~~24/Nov/14~~	~~1,878~~	~~10~~	~~2,000~~		~~122~~	~~Crashed~~	
NPI	F Main workshop Completion Date	24/Nov/14		24/Nov/14	-	-		-	-	-	Milestone
PE	G Tendering Process	18/Jan/13	252	26/Sep/13	-	252	-	-	-	-	EPCM services not included
PE	H Contract Award	26/Sep/13		26/Sep/13	-	-		-	-	-	Milestone
PE	I Fabrication & Delivery- Wheelshop	26/Sep/13	425	24/Nov/14	31,360	380	39,500	45	8,140	107	Data quoted from supplier
PE	~~J Installation- Wheelshop~~	~~25/Nov/14~~	~~70~~	~~02/Feb/15~~	~~16,465~~	~~70~~	~~19,300~~		~~2,835~~	~~Crashed~~	
PE	K Installation- All PE Exclude Wheelshop	03/Aug/14	184	02/Feb/15	28,459	170	32,540	14	4,081	89	
PE	~~L Commissioning- All PE~~	~~03/Feb/15~~	~~110~~	~~23/May/15~~	~~20,160~~	~~110~~	~~22,850~~		~~2,690~~	~~Crashed~~	
PE	~~M Operation Ramp-Up~~	~~24/May/15~~	~~70~~	~~01/Aug/15~~	~~12,096~~	~~70~~	~~12,990~~		~~894~~	~~Crashed~~	
Project Completion Date		01/Aug/15		01/Aug/15				-	-	-	Milestone



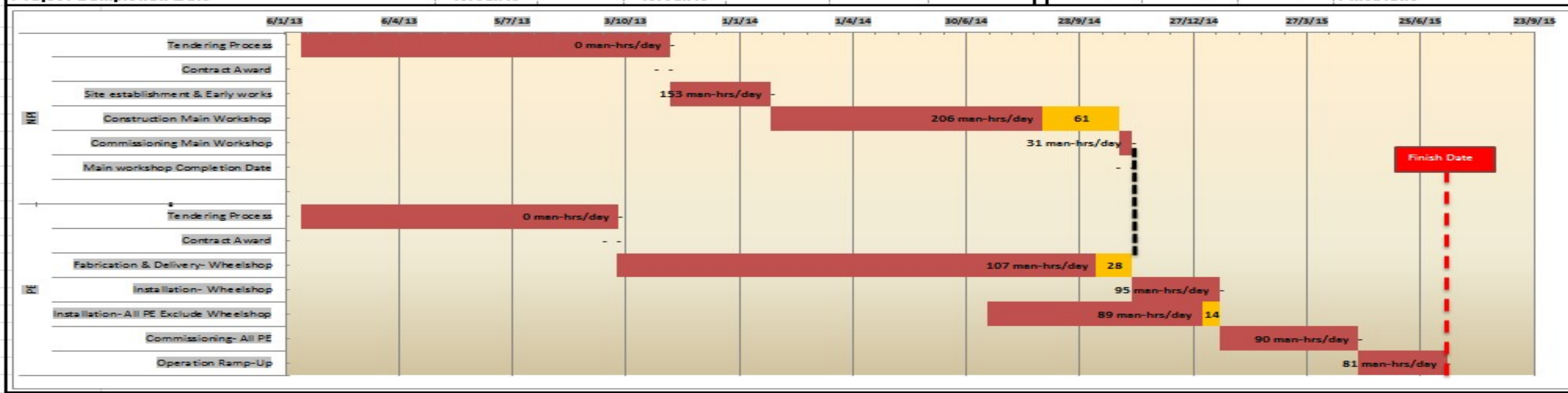
- **Crash a portion of “Fabrication & Delivery Wheel shop” duration and “NPI Site establishment”:**

Both “Fabrication & Delivery-Wheel shop” and “NPI Site establishment” can be crashed in 17 days.

New forecast finish date: 15 July 15 and additional direct man-hours: (107 hrs/day * 17 days) + (153 hrs/day * 17 days) = 4,420 hrs

TABLE 8-39 Crashing- Activity I+K+C

OCRS project Cost & Time Trade off												
Contract Package	Activity Description	Original Schedule data				Crash data		Time Saving-Days	Extra required Man-Hours	Extra required Man-Hours per day	Comments
		(*)Start	Duration	(*)Finish	Required Manhours	Crash Duration	Crash Man-hours				
Project Start date		07/Jan/13									
NPI	A Tendering Process	18/Jan/13	293	06/Nov/13	-	293	-	-	-	-	EPCM services not included
	B Contract Award	06/Nov/13	-	06/Nov/13	-	-	-	-	-	-	Milestone
	C ~~Site establishment & Early works~~	~~07/Nov/13~~	~~80~~	~~25/Jan/14~~	~~20,855~~	~~80~~	~~23,450~~		~~2,595~~	~~Crashed~~	
	D Construction Main Workshop	26/Jan/14	276	28/Oct/14	104,812	215	117,380	61	12,568	206	
	E ~~Commissioning Main Workshop~~	~~29/Oct/14~~	~~10~~	~~07/Nov/14~~	~~1,878~~	~~10~~	~~2,000~~		~~122~~	~~Crashed~~	
	F Main workshop Completion Date	07/Nov/14		07/Nov/14	-	-		-	-	-	Milestone
PE	G Tendering Process	18/Jan/13	252	26/Sep/13	-	252	-	-	-	-	EPCM services not included
	H Contract Award	26/Sep/13		26/Sep/13	-	-		-	-	-	Milestone
	I Fabrication & Delivery- Wheelshop	26/Sep/13	408	07/Nov/14	31,360	380	39,500	28	8,140	107	Data quoted from supplier
	J ~~Installation - Wheelshop~~	~~08/Nov/14~~	~~70~~	~~16/Jan/15~~	~~16,465~~	~~70~~	~~19,300~~		~~2,835~~	~~Crashed~~	
	K Installation- All PE Exclude Wheelshop	17/Jul/14	184	16/Jan/15	28,459	170	32,540	14	4,081	89	
	L ~~Commissioning- All PE~~	~~17/Jan/15~~	~~110~~	~~06/May/15~~	~~20,160~~	~~110~~	~~22,850~~		~~2,690~~	~~Crashed~~	
	M ~~Operation Ramp-Up~~	~~07/May/15~~	~~70~~	~~15/Jul/15~~	~~12,096~~	~~70~~	~~12,990~~		~~894~~	~~Crashed~~	
Project Completion Date		15/Jul/15		15/Jul/15				-	-	-	Milestone



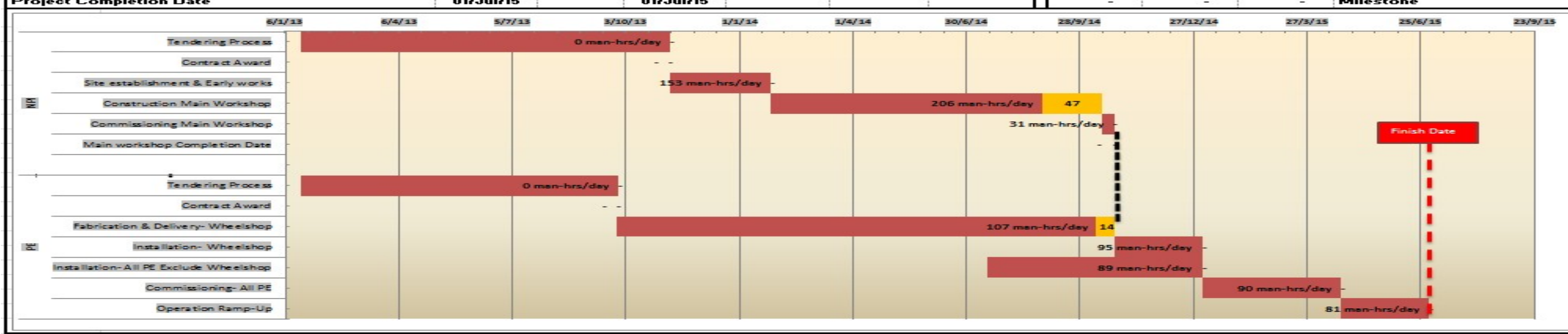
- **Crash a portion of "Fabrication & Delivery Wheel shop" duration, "NPI Construction workshop" and" Installation all PE":**

Both "Fabrication & Delivery-Wheel shop", "NPI Construction workshop" and" Installation all PE" can be crashed in 14 days.

New forecast finish date: 01 July 15 and additional direct man-hours: (107 hrs/day * 14 days) + (206 hrs/day * 14 days) + (153 hrs/day * 14 days) = 5,628 hrs

TABLE 8-40 Crashing- Activity I+K+D

OCRS project Cost & Time Trade off												
Contract Package		Activity Description	Original Schedule data				Crash data		Time Saving-Days	Extra required Man-Hours	Extra required Man-Hours per day	Comments
			(*)Start	Duration	(*)Finish	Required Manhours	Crash Duration	Crash Man-hours				
Project Start date			07/Jan/13									
NPI	A	Tendering Process	18/Jan/13	293	06/Nov/13	-	293	-	-	-	-	EPCM services not included
	B	Contract Award	06/Nov/13	-	06/Nov/13	-	-	-	-	-	-	Milestone
	C	~~Site establishment & Early works~~	~~07/Nov/13~~	~~80~~	~~25/Jan/14~~	~~20,855~~	~~80~~	~~23,450~~		~~2,595~~	~~Crashed~~	
	D	Construction Main Workshop	26/Jan/14	262	14/Oct/14	104,812	215	117,380	47	12,568	267	
	E	~~Commissioning Main Workshop~~	~~15/Oct/14~~	~~10~~	~~24/Oct/14~~	~~1,878~~	~~10~~	~~2,000~~		~~122~~	~~Crashed~~	
	F	Main workshop Completion Date	24/Oct/14		24/Oct/14	-	-		-	-	-	Milestone
PE	G	Tendering Process	18/Jan/13	252	26/Sep/13	-	252	-	-	-	-	EPCM services not included
	H	Contract Award	26/Sep/13		26/Sep/13	-	-		-	-	-	Milestone
	I	Fabrication & Delivery- Wheelshop	26/Sep/13	394	24/Oct/14	31,360	380	39,500	14	8,140	107	Data quoted from supplier
	J	~~Installation - Wheelshop~~	~~25/Oct/14~~	~~70~~	~~02/Jan/15~~	~~16,465~~	~~70~~	~~19,300~~		~~2,835~~	~~Crashed~~	
	K	~~Installation - All PE Exclude Wheelshop~~	~~17/Jul/14~~	~~170~~	~~02/Jan/15~~	~~28,459~~	~~170~~	~~32,540~~		~~4,081~~	~~Crashed~~	
	L	~~Commissioning - All PE~~	~~03/Jan/15~~	~~110~~	~~22/Apr/15~~	~~20,160~~	~~110~~	~~22,850~~		~~2,690~~	~~Crashed~~	
	M	~~Operation Ramp-Up~~	~~23/Apr/15~~	~~70~~	~~01/Jul/15~~	~~12,096~~	~~70~~	~~12,990~~		~~894~~	~~Crashed~~	
Project Completion Date			01/Jul/15		01/Jul/15				-	-	-	Milestone



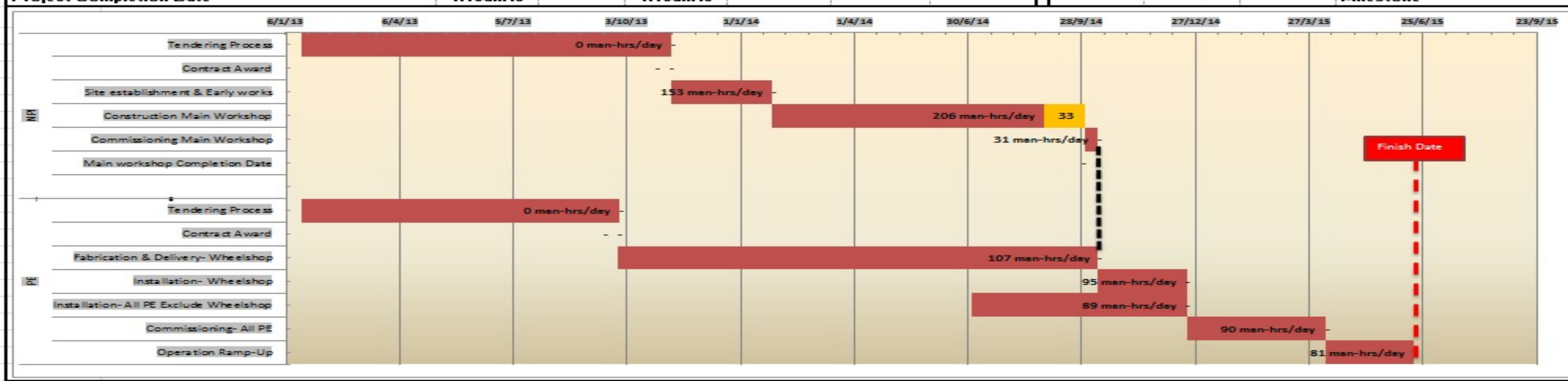
- **Crash “Fabrication & Delivery Wheel shop” duration, and a portion of “NPI Construction workshop”:**

Both “Fabrication & Delivery-Wheel shop” and “NPI Construction workshop” can be crashed in 14 days.

New forecast finish date: 01 July 15 and additional direct man-hours: (107 hrs/day * 14 days) + (206 hrs/day * 14 days) = 4,382 hrs

TABLE 8-41 Crashing- Activity I+D

OCRS project Cost & Time Trade off													
Contract Package		Activity Description	Original Schedule data				Crash data		Time Saving-Days	Extra required Man-Hours	Extra required Man-Hours per day	Comments
			(*)Start	Duration	(*)Finish	Required Manhours	Crash Duration	Crash Man-hours				
Project Start date			07/Jan/13									
NPI	A	Tendering Process	18/Jan/13	293	06/Nov/13	-	293	-	-	-	-	EPCM services not included
	B	Contract Award	06/Nov/13	-	06/Nov/13	-	-	-	-	-	-	Milestone
	C	~~Site establishment & Early works~~	~~07/Nov/13~~	~~80~~	~~25/Jan/14~~	~~20,855~~	~~80~~	~~23,450~~		~~2,595~~	~~Crashed~~	
	D	Construction Main Workshop	26/Jan/14	248	30/Sep/14	104,812	215	117,380	33	12,568	381	
	E	~~Commissioning Main Workshop~~	~~01/Oct/14~~	~~10~~	~~10/Oct/14~~	~~1,878~~	~~10~~	~~2,000~~		~~122~~	~~Crashed~~	
	F	Main workshop Completion Date	10/Oct/14		10/Oct/14	-	-		-	-	-	Milestone
PE	G	Tendering Process	18/Jan/13	252	26/Sep/13	-	252	-	-	-	-	EPCM services not included
	H	Contract Award	26/Sep/13		26/Sep/13	-	-		-	-	-	Milestone
	I	~~Fabrication & Delivery- Wheelshop~~	~~26/Sep/13~~	~~380~~	~~10/Oct/14~~	~~31,360~~	~~380~~	~~39,500~~		~~8,140~~	~~Crashed~~	Data quoted from supplier
	J	~~Installation- Wheelshop~~	~~11/Oct/14~~	~~70~~	~~19/Dec/14~~	~~16,465~~	~~70~~	~~19,300~~		~~2,835~~	~~Crashed~~	
	K	~~Installation- All PE Exclude Wheelshop~~	~~03/Jul/14~~	~~170~~	~~19/Dec/14~~	~~28,459~~	~~170~~	~~32,540~~		~~4,081~~	~~Crashed~~	
	L	~~Commissioning- All PE~~	~~20/Dec/14~~	~~110~~	~~08/Apr/15~~	~~20,160~~	~~110~~	~~22,850~~		~~2,690~~	~~Crashed~~	
	M	~~Operation Ramp-Up~~	~~09/Apr/15~~	~~70~~	~~17/Jun/15~~	~~12,096~~	~~70~~	~~12,990~~		~~894~~	~~Crashed~~	
Project Completion Date			17/Jun/15		17/Jun/15				-	-	-	Milestone



- **Crashing Summary:**

Below is the outcome of the project crashing process as shown in Table 8-42 and Figure 8-16:

- Project optimum duration: 632 days
- Project optimum completion date: 01 Aug 15
- 102 days schedule savings to get bonus or recover any possible delays
- 13,493 hrs savings in comparison to budgeted hours

TABLE 8-42 Project Crashing Summary

Project Crashing Summary							
	Project Duration	Project Finish Date	Direct Man-Hours	In-Direct Man-Hours	Total Man-Hours	Comments	Optimum Date & Duration
Baseline	734	11-Nov-15	435,511	187,904	623,415	Baseline schedule & quantity data	
Stage 1- Crash M	723	31-Oct-15	436,405	185,088	621,493	Additional Direct hours: 81 @ 11 days = 894 hrs	
Stage 2- Crash L	693	01-Oct-15	439,095	177,408	616,503	Additional Direct hours: 90 @ 30 days = 2,690 hrs	
Stage 3- Crash J	663	01-Sep-15	441,930	169,728	611,658	Additional Direct hours: 95 @ 30 days = 2,835 hrs	
Stage 4- Crash a portion of I & K	636	05-Aug-15	447,222	162,816	610,038	(107 @ 27 days) + (89 @ 27 days)= 5,292 hrs	
Stage 5- Crash E and a portion of I & K	632	01-Aug-15	448,130	161,792	609,922	(107 @ 4 days) + (89 @ 4 days) + (31 @ 4 days)= 908 hrs	⇐
Stage 6- Crash C and a portion of I	615	15-Jul-15	452,550	157,440	609,990	(107 @ 17 days) + (153 @ 17 days)= 4,420 hrs	
Stage 7- Crash a portion of D & I and K	601	01-Jul-15	458,178	153,856	612,034	(107 @ 14 days) + (89 @ 14 days) + (206 @ 14 days) = 5,628 hrs	
Stage 8- Crash I and a portion of D	587	17-Jun-15	462,560	150,272	612,832	(107 @ 14 days) + (206 @ 14 days)= 4,382 hrs	

NPI	A	Tendering Process
	B	Contract Award
	C	Site establishment & Early works
	D	Construction Main Workshop
	E	Commissioning Main Workshop
	F	Main workshop Completion Date
PE	G	Tendering Process
	H	Contract Award
	I	Fabrication & Delivery- Wheelshop
	J	Installation- Wheelshop
	K	Installation- All PE Exclude Wheelshop
	L	Commissioning- All PE
	M	Operation Ramp-Up

Notes:

* For Crashing purpose, Project duration is calculated based on the earliest date of construction phase (07 Nov 13)

* Optimum Project Duration: 632 days

* Optimum Project Finish date: 01 Aug 15

* Man-Hours Saving: 623,415 hrs - 609,922 hrs = 13,493 hrs

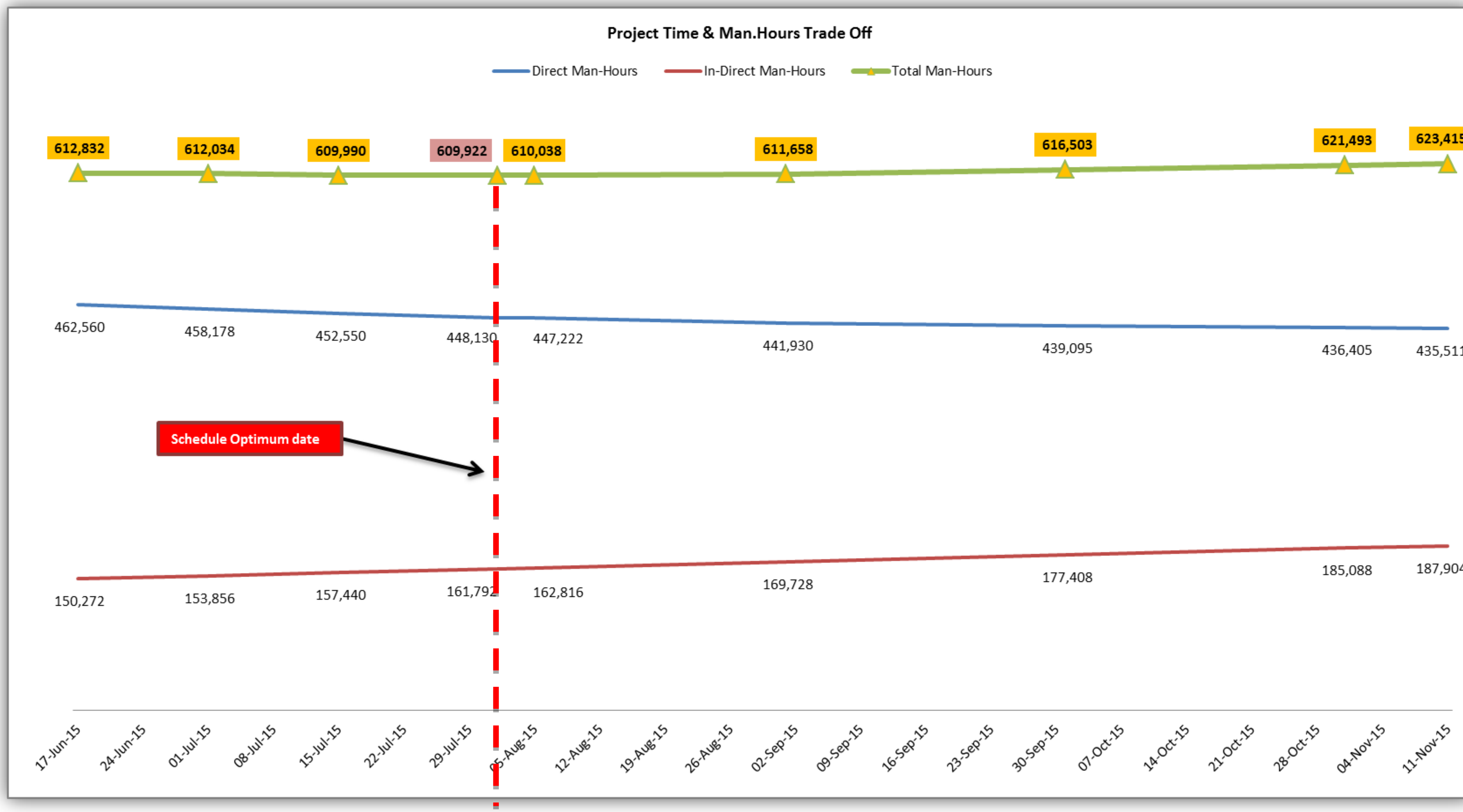


FIGURE 8-16 **Project Time & Man hours Trade off Graph**

8.21. Project Cash flow

Once a project schedule is developed in the planning process, it is important to make sure that the planned expenditures (cash flow) extracted from the resource loaded schedule align with the available funds [Lock D, 2004].

Funding limit reconciliation is a technique that describes adjustment of the funding limits and estimated costs by refining the scope and schedule of project activities. In addition, expenditure of the funds should be reconciled with the funding limits of the project.

Most clients have limited resources to fund their projects and this can affect the cash flow of the entire organization. In most cases, the project funding is based quarterly or on the fiscal year. It is important for the project budget to follow the constraints imposed by the funding limit reconciliation.

Table 8-43 illustrates the availability of the funds for the "construction & installation" phase on a quarterly basis.

TABLE 8-43 Funds for Construction & Installation

Client Available Budget (Direct Hours for Construction/Installation phase)			
Year	Period	Budgeted Hrs	Cum. Budgeted Hrs
2014	Jan 14 ~ Mar 14	20,000	20,000
	Apr 14 ~ Jun 14	50,000	70,000
	Jul 14 ~ Sep 14	50,000	120,000
	Oct 14 ~ Dec 14	70,000	190,000
2015	Jan 15 ~ Mar 15	30,000	220,000
	Apr 15 ~ Jun 15	0	220,000

Project planned expenditure or cash flow, normally at S-Curve shape can be extracted from the resource loaded plan. As shown in Figure 8-17, in OCRS project, planned hours for construction & installation phase exceed about 12,000 hrs the limited funds in month September 14.

In this case, the required budget is approximately 10% greater than the available funds and may not cause an issue in providing extra budget at this period by the client. That means, allocated funds are sufficient to support the project schedule and to meet the planned dates.

A significant slippage between required budget and available funds may lead to a consequent reschedule of the project activities to meet the rate of expenditure.

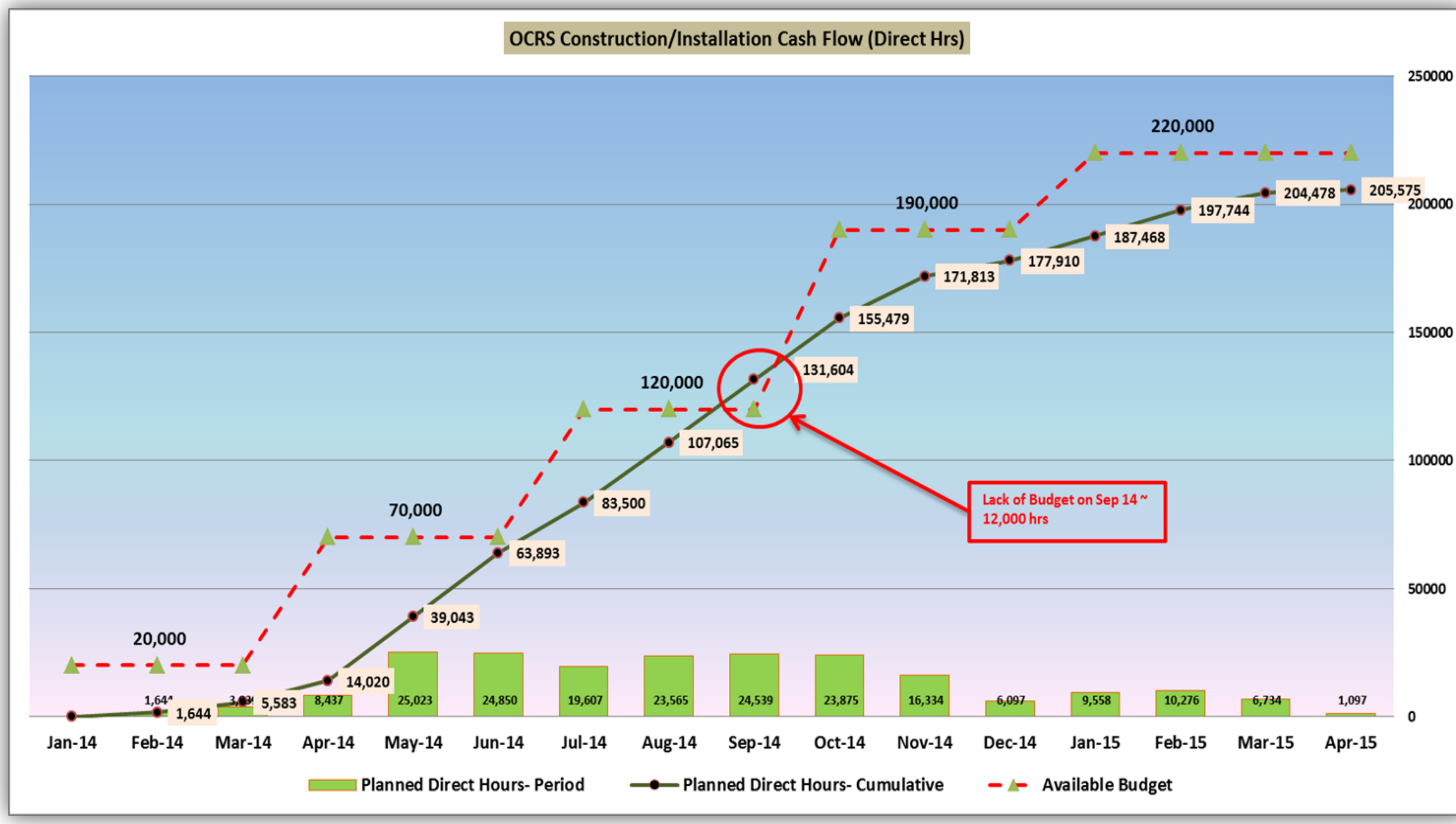


FIGURE 8-17 **Project Cash Flow**

If project periodic funds are restricted by the client and to cover the budgeted hour's slippage (12,000 hrs) in month Sep 14 without effecting project targeted completion date, it is strongly recommended to use "Total Float concept". By reviewing the schedule activities and filtering the list of non-critical works in construction/installation phase, the warehouse building process with the value of 14,060 hrs can be selected to utilise its float.

As per client instruction, all construction materials and process equipment can be stored in the temporary warehouse, however all PE shall be installed in the main workshop upon arrival on site. Therefore, warehouse building is not considered critical to construct at an early stage however shall be completed prior to landscaping.

Figure 8-18 shows construction of the warehouse is planned to start on 24 April 14 and can be postponed to 06 October 14 without any changes to the project target date. Using a portion of/or all float for each non-critical activity will assist to compensate the budget deficit by moving the required budget (14,060 hrs) to the period that enough funds are available (Oct 14 and later).

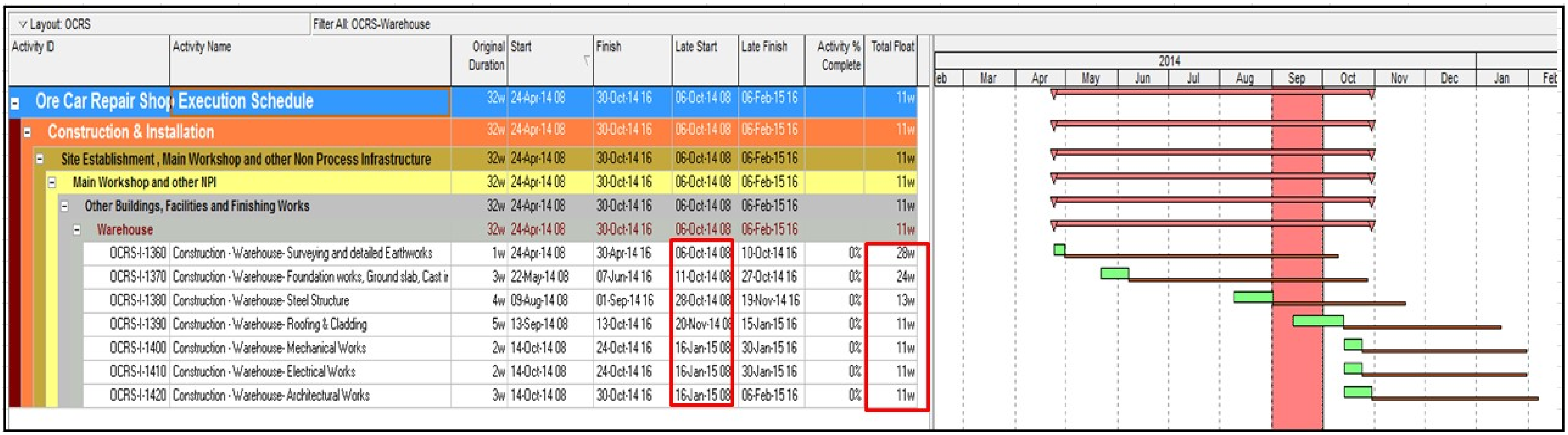


FIGURE 8-18 **Mitigation of Project Budget Deficit**

8.22. Risks and risk control action plan

The risk assessment considers the factors that may influence the risk profile of the project through all stages of the project life cycle. The outcome is a creation of the project detailed risk register. The development of the risk register considered a broad variety of factors in risk identification, which is necessary for the risk register to be able to remain a pertinent document throughout the delivery of the project.

It is vital that the risk register remain a "live" document throughout the delivery of the project, with the risk register maintained and updated as the project evolves. Consideration during the planning phase of all known material risks that may emerge in the various project phases enables early identification and implementation of appropriate action plans for managing these risks.

Controls in a project context represent a combination of current controls, that have already been implemented, and controls that are planned and budgeted which will be implemented at the relevant project life cycle stage. The project recognises the importance of this activity and will review the effectiveness of controls as they are implemented and update the risk register accordingly.

Table 8-44 is an example of the control action plan for "Adverse weather risk"

TABLE 8-44 An example of Risk Control Action Plan

			Sevirity	30	**Schedule impact:**	30 days
	Risk Rating	90	**Likelihood**	3	**Cost impact:**	60 mil$
Risk Issue	Weather					
Event	Adverse Weather					
Causes	* Cyclonic Activitiy * Significant rainfall and subsequent flooding * Operations utilising construction equipment post event to repaire potential damage * Inadequate identification of construction methodology / Execution strategy to mitigate adverse weather impacts * Construction commencing in wet season					
Preventive Controls	* Execution schedule considers wet season * Monitor major weather activity and take evasive action * Project location on high ground and removed from nearby creek * Following process for weather perdiction and cyclone warning * Historical weather data available					
Impacts	* Inability tocomplete sitewide earthworks or access construction sites for an extended period resulting in schedule delays * Construction works stopped impacting schedule due to flooding * Rework * HSEC impacts * Additional costs					
Mitigating Controls	* Incident management * Emergency response * Contingency planning * Provision in baseline schedule for inclement weather * Road mitigations for weather conditions					

8.23. Ranges and Sensitivities

Range analysis explores the uncertainty in financial, schedule and other quantitative features of a forecast. It applies estimates of uncertainties or sensitivities in components of the forecasts to evaluate the overall uncertainty in the forecast outcome.

A range analysis serves two main purposes:

- The process of examining uncertainty in the components of a forecast and comparing results yields insights that contribute to the realism and integrity of the forecast.
- The aggregate uncertainty forecast provides a basic for setting targets, contingencies, and commitments.

The technical aspects of range analysis are usually based on Monte Carlo simulation modelling. This is a proven means of integrating and aggregating uncertain values contributing to the cost, schedule, and other quantitative features of a project.

To prepare and use the Monte Carlo simulation model, it is necessary to understand the source of uncertainties (sensitivities) affecting a forecast. Once these sensitivities have been determined, they are input into the Monte Carlo analysis and a series of forecast iterations are run using combinations of these sensitivities. The number of iterations typically is +1000 and the model must represent these sensitivities realistically and link them to the aggregate forecast. The result of modelling will typically give a bell curve of results with the p50 outcome (probabilistic outcome) not necessarily aligning with the single point outcome of the forecast.

Tornado diagrams are another classic tool of sensitivity analysis [Maylor H, 2010] for decision analysis. They display sensitivities in descending order where management can see the positive or negative impacts of a change in variables and assumptions.

It is crucial that each project is subject to critical examination to identify factors that could cause a material variation from the most likely outcome. However, it is also critical to make the range analysis process as cost-effective as possible. Variations arising from the following or similar matters are considered in the range analysis:

- Uncertainty in detailed design development affecting quantities and possible rates
- Vendor information exposure

- Unforeseen site conditions
- Approval processes
- Inclement weather
- Workforce issues such as productivity and labour arrangement
- Interactions with operations or third parties
- Necessary external dependencies such as procurement process
- The commercial and economic environment

Table 8-45 concerns a single factor or source of uncertainty. It captures information in a carefully designed sequence that minimise bias and enhances the reliability of uncertainty forecasts. The main descriptive fields are explained below:

TABLE 8-45 Source of Uncertainty Template

Field	**Purpose**
Assumptions	Highlight an approach to the common standpoint
Status of work to date	Identify the level of detail
Source of uncertainty	Describe the circumstances that might cause the outcome to differ from what has been assumed in the original estimates
Pessimistic Scenario	Outline the circumstances that would be seen if the outcome was less desirable than assumed in the estimates
Optimistic Scenario	Outline the circumstances that would be seen if the outcome was more desirable than assumed in the estimates
Likely Scenario	Outline the circumstances that are actually expected to occur

Table 8-46 is an example of the uncertainty forecasts for the main workshop concrete/steel structure works:

Table 8-46 An Example of Uncertainty Forecasts

Item	Assumptions	Status of Work to date	Sources of Uncertainty	Pessimistic Scenario	Optimistic Scenario	Likely Scenario
Concrete	Construct in dry season	Baching plant will be installed on site	Contractor productivity	+1 mth	-1 mth	As planned
	Contractor is on site with other work	Contract award is in progress	Baching plant reliability , supply reliability	Contrctor fails to meet target productivity	Efficient contractor	
	Single shift		Structural failure during construction	Concrete supply is unreliable	Optimise construction practice	
			Change of wrehouse size	Severe wet weather	Detailed design results in tinner slab	
			Change of AGV type	Scope creep on concrete aprons		
Steel structure	Freo steel supply	Engineering design 30% done	Different erction methodologies	+1.5 mth	-1 mth	As planned
	Conventional stick build with large steel member frame	will be fabricated by NPI contractor	Ridge vent sizeing could change significantly	detailed design results in more tonnage than allowed	detailed design results in less tonnage	
			Warehouse sizing may change	Significant requirements for service droppers	More efficient build methodologies	
				Warehouse size increases	Significant savings in ridge vent design	

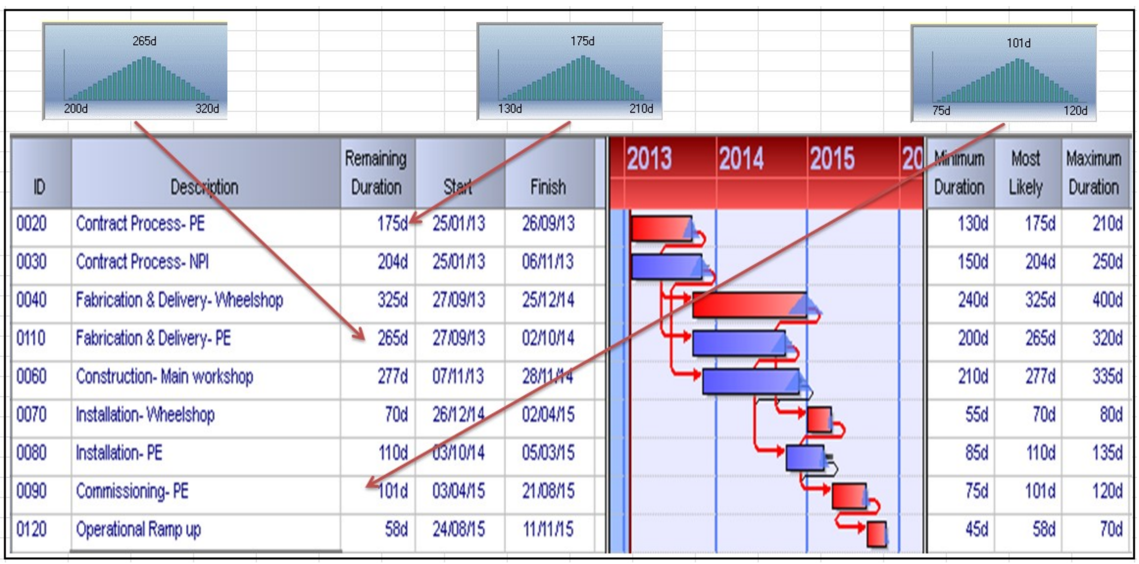
8.24. Schedule risk analysis practice

Schedule Range Analysis is a process that measures most likely and probabilistic range estimates for duration of all activities affecting the project baseline schedule. In this regard, following a guideline is commonly implemented by leading construction and oil & gas companies that can be considered as efficient schedule range analysis practice:

- Project scope of work as defined in project execution plan is fixed and approved by client
- Project execution schedule is approved and is saved as a baseline schedule (most likely completion date).
- Risk data tables are updated and agreed by the team. Only moderate and high-level risks can be considered for schedule range analysis.
- Only critical activities and near critical activities extracted from baseline schedule are used for Mont Carlo simulation.
- Frequency (at least 1000 iteration) and distribution function (Normal, Beta, Triangular, etc.) for each selected activity can be determined by client.
- Range workshops are conducted by Engineers to estimate the best duration, optimistic duration, most likely duration, pessimistic

duration and worst duration for each selected activities. At least three scenarios (optimistic, most likely, and pessimistic) are essential to perform the risk simulation. These estimates should be refined by Engineers during the planning phase and finally must be approved by the client.

- Schedule range analysis can be run by approved risk management software (e.g. Oracle Primavera risk analysis).
- The range analysis data for nominated project KPI milestones is established for the project based on the approved baseline schedule. For risk profile purposes, for instance, the range between 20% and 80% probability can be informative for the client, although the variation becomes too high in marginal areas.
- The Figure 8-19 below indicates the summary of the above processes for the OCRS project applying triangle probabilistic distribution for critical and near critical activities at the summary level.



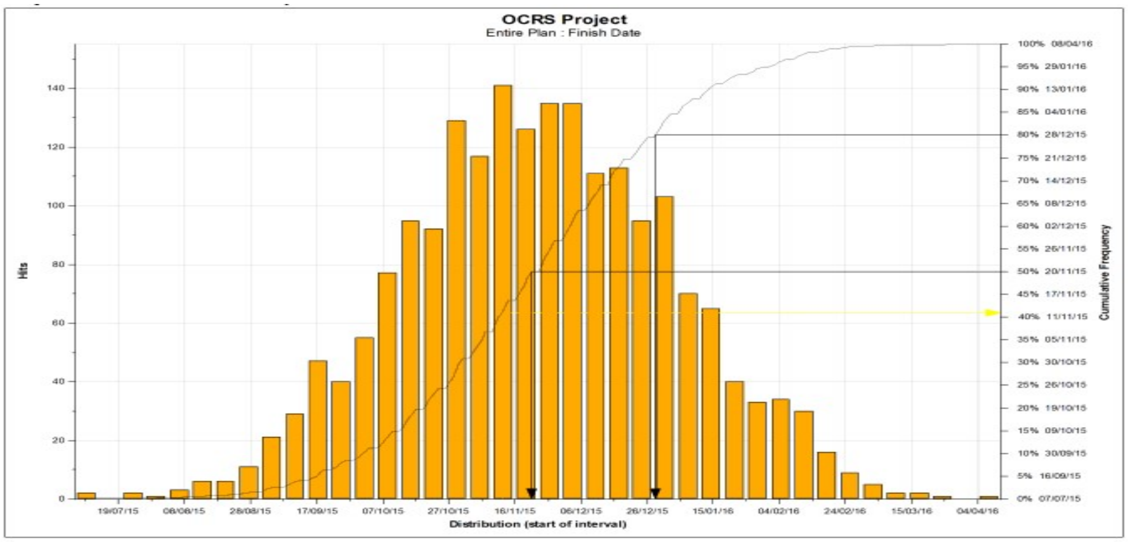
ID	Description	Remaining Duration	Start	Finish	Minimum Duration	Most Likely	Maximum Duration
0020	Contract Process- PE	175d	25/01/13	26/09/13	130d	175d	210d
0030	Contract Process- NPI	204d	25/01/13	06/11/13	150d	204d	250d
0040	Fabrication & Delivery- Wheelshop	325d	27/09/13	25/12/14	240d	325d	400d
0110	Fabrication & Delivery- PE	265d	27/09/13	02/10/14	200d	265d	320d
0060	Construction- Main workshop	277d	07/11/13	28/11/14	210d	277d	335d
0070	Installation- Wheelshop	70d	26/12/14	02/04/15	55d	70d	80d
0080	Installation- PE	110d	03/10/14	05/03/15	85d	110d	135d
0090	Commissioning- PE	101d	03/04/15	21/08/15	75d	101d	120d
0120	Operational Ramp up	58d	24/08/15	11/11/15	45d	58d	70d

FIGURE 8-19 **Schedule risk Data and Probabilistic distribution curve**

The below key outcomes are expected after running schedule range analysis:

8.24.1 Project Likelihood distribution

Once the activities` duration ranges and distributions have been determined, the schedule risk analysis can determine the level of risk for the entire schedule. At the end of the of the entire simulation, project completion and important milestone dates computed from all iterations are collected and arrayed in graphs and tables showing the probability distribution or relative frequency, of all possible dates. Figure 8-20 indicates project likelihood distribution (Bell curve) [Mantel S. Meredith J, 2011]and a cumulative distribution (S-Curve) for a total project completion date.



Title	Value
Minimum	07/07/15
Maximum	08/04/16
Mean	21/11/15
Bar Width:	week

FIGURE 8-20 **Project Likelihood Bell Curve**

The CPM completion date is often not the most likely project completion date in almost all cases. A look at the bell-shaped distribution reveals the following:

- An estimated 42% chance is calculated to complete the project by 11 Nov 15 resulting in the completion date estimate being more than likely reasonable. The confidence in completion by 11 Nov 15 is likely to be seen favourable from a project performance perspective.
- The project most likely can be completed at 21 Nov 15 (P mean). The common-sense notion that adding most likely durations along a critical path will result in the most likely project completion date,

that is simply incorrect, in most cases. Based on the above results, the most likely completion date would be approximately 10 days overrun of the project duration in the baseline schedule.

- 80% likelihood of the project success is expected at 28 Dec 15. This date (P80) is also benchmarked to determine the schedule contingencies in many companies that eventually will be considered in the baseline plan. In OCRS project and as per client risk management procedures, contingencies & project KPI will be computed based on the conservative schedule that has an 80% likelihood of success P (80).
- There is 20% chance of completing the project scope by 19 Oct 15. The risk analysis establishes that 11 Nov 15 is optimistic and any agreement to this date will not result in any major issues in this project.
- Without the risk analysis, the existence or degree of trouble is unknown.

8.24.2 Duration Sensitivity

Schedule risk analysis is a simple and effective technique to extract sensitivity information of individual activities to assess the potential impact of uncertainty on the project's final duration. Duration sensitivity for each task is a correlation between its duration and project duration.

It is very important for project managers to focus on the 'risky' tasks that may have an impact to the project objectives.

The duration sensitivity chart identifies activities and paths that tend to be associated with project risk. Below tornado graph demonstrates duration of the activity "Fabrication & Delivery- wheel shop" has the most impact to the overall project duration through the iterations.

"Contract Process- PE" is the next activity that project manager should consider as a risky task. Hence, all the high rank risks associated to the above activities shall be mitigated to the acceptable level and effective way.

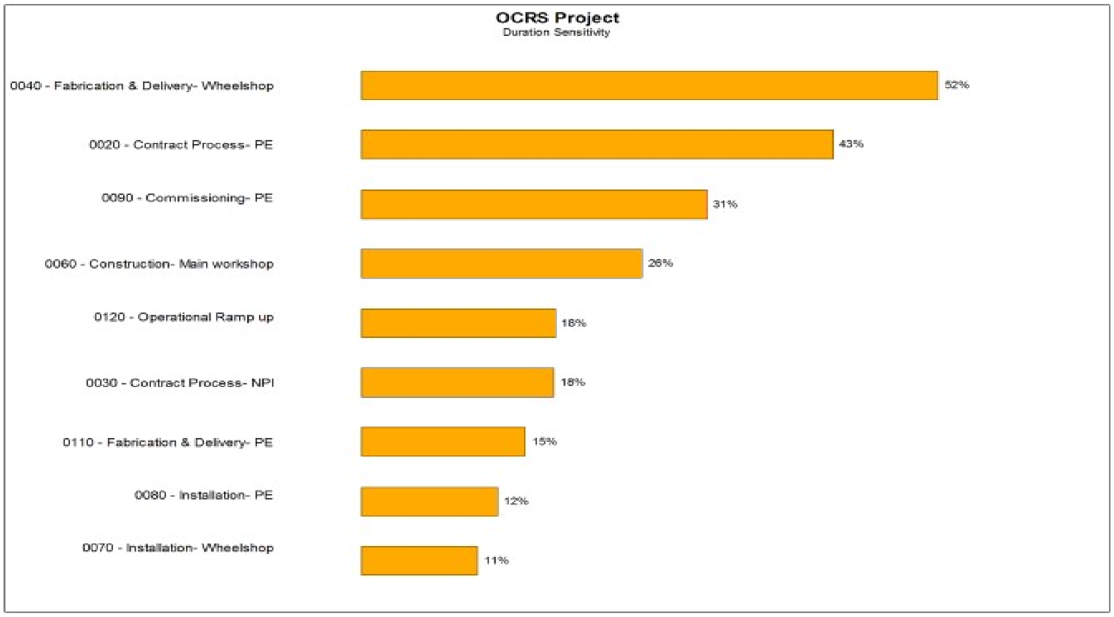


FIGURE 8-21 **Project Duration Sensitivity- Tornado Graph**

8.24.3 Schedule Critically Index

The criticality index of a task is the proportion of the iterations in which the task was considered critical. It measures the probability that an activity lies on the critical path. This index has been implemented in many software packages however it doesn't necessarily mean that high critically index tasks have a high impact on the overall project duration.

Risk critically represents the percentage of simulation iterations that an activity or milestone is on the critical path. As shown in Figure 8-22, both "Commissioning-PE" and "Operational Ramp up" 100% were in the critical path during the 2000 iterations.

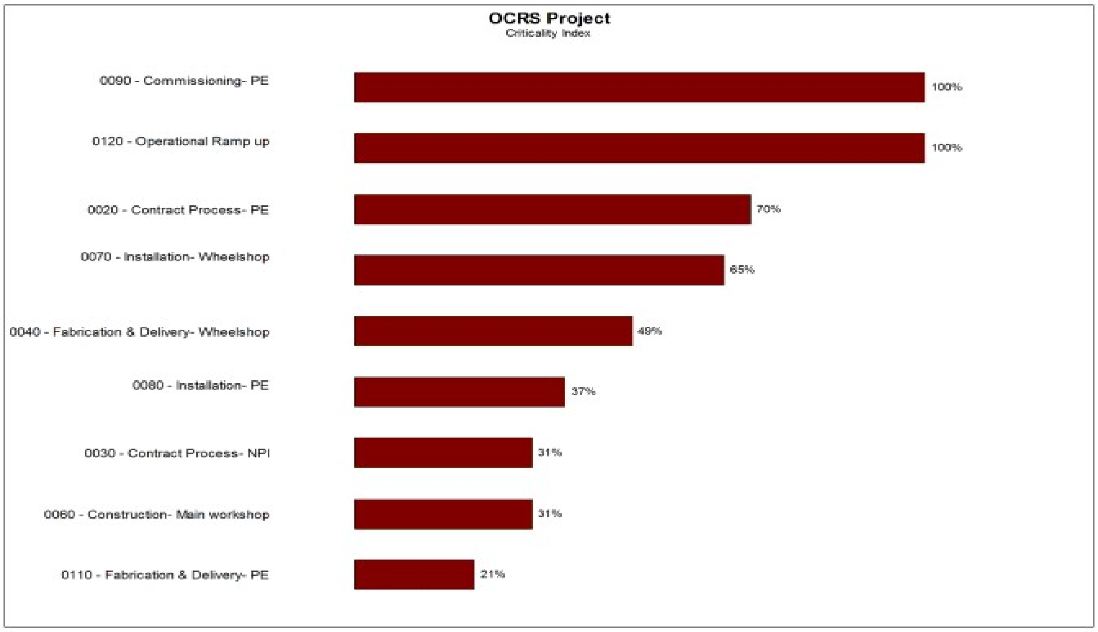


FIGURE 8-22 **Project Schedule Critically Index - Tornado Graph**

8.24.4 Schedule Sensitivity Index

The Schedule Sensitivity Index of a task is calculated by multiplying its criticality index by the ratio of its variance against the variance of the project [Vanhoucke,M, 2011]:

$$SSI = \frac{\text{St Dev Activity Duration} * \text{Critically Index}}{\text{StDev Project Duration}}$$

EQUATION 8-2 **Schedule Sensitivity Index- SSI**

According to this analysis shown in Figure 8-23, “Fabrication & Delivery- Wheel shop” activity is the biggest risk driver in the schedule. Using this information, the project manager and supplier can work together to ensure the PE will be delivered on schedule.

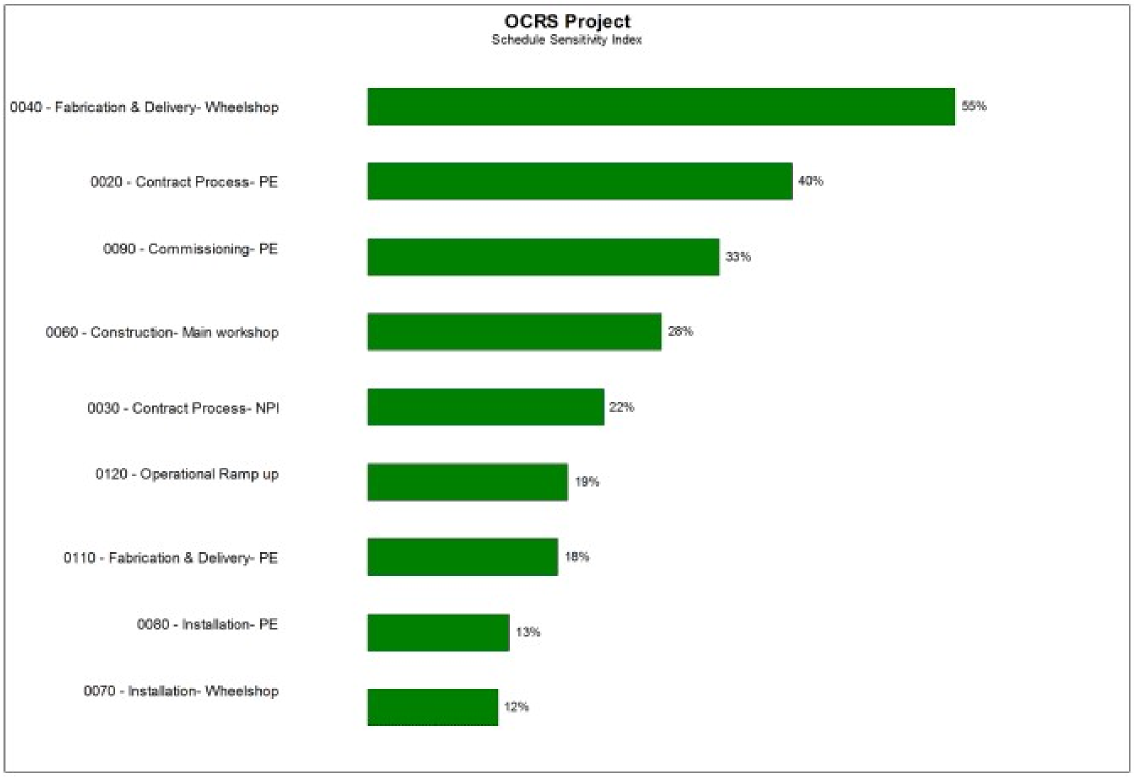


FIGURE 8-23 **Project Schedule Sensitivity Index - Tornado Graph**

8.24.5 Schedule Cruciality Index

The cruciality of a task is calculated by multiplying its duration sensitivity by its criticality index [Oracle Primavera Risk Analysis, 2011].

$$SCI = \text{Duration Sensitivity} * \text{Critical Index}$$

EQUATION 8-3 **Schedule Cruciality Index- SCI**

The index reflects the relative importance of an activity and calculates the portion of total duration uncertainty that can be explained by the uncertainty of an activity. However, the relation between an activity duration and the total project duration often follows a non-linear relation with an absolute value typically between 0 and 1

The below tornado graph shown in Figure 8-24 indicates the “Fabrication & Delivery-Wheel shop” activity has the maximum correlation with the project overall schedule. Hence, the project manager should pay more attention to the risks associated with this activity to deliver the project scope at the targeted completion date.

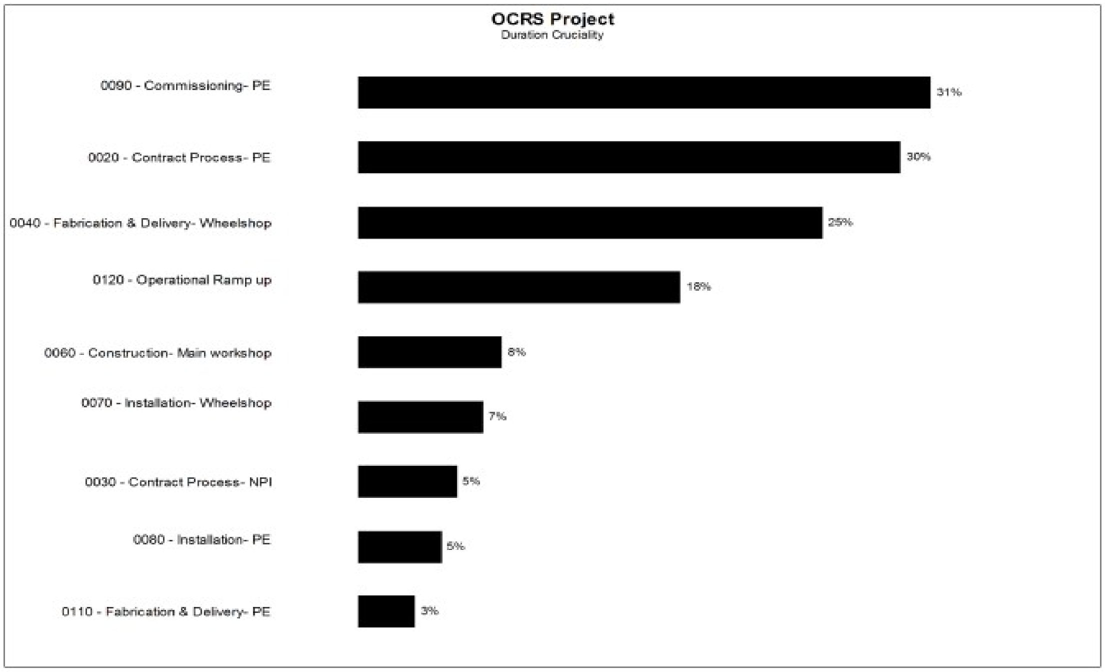


FIGURE 8-24 **Duration Cruciality Index - Tornado Graph**

8.25. Contingency

Contingency is a specific provision that is added to the project base estimate to account the uncertainty associated with project scope of work. As per client instruction in OCRS project, contingency is the additional amount added to the project value to bring the expected project value to the conservative value (P80).

$$\text{Contingency Reserve} = \text{Conservative Value (P80)} - \text{Project Base estimate}$$

EQUATION 8-4 **CONTINGENCY RESERVES**

It is important to note that contingency is a provision only for those items that are within the defined project scope. Changes to the scope of work usually are funded from the client contingency sum. Contingency is an integral cost element to cover the statistical probability of the occurrence of unforeseeable elements of cost due to uncertainty, intangibles and unforeseen occurrence of future events.

Accordingly, schedule risks are the potential risks and issues the project may potentially encounter in meeting deadlines for the final deliverables.

Schedule contingency is the amount of time allocated between the schedule deterministic completion date on a project KPI milestone and the range analysis completion date (P80) for that project KPI milestone. The schedule contingency is shown on the management summary schedule as a single activity.

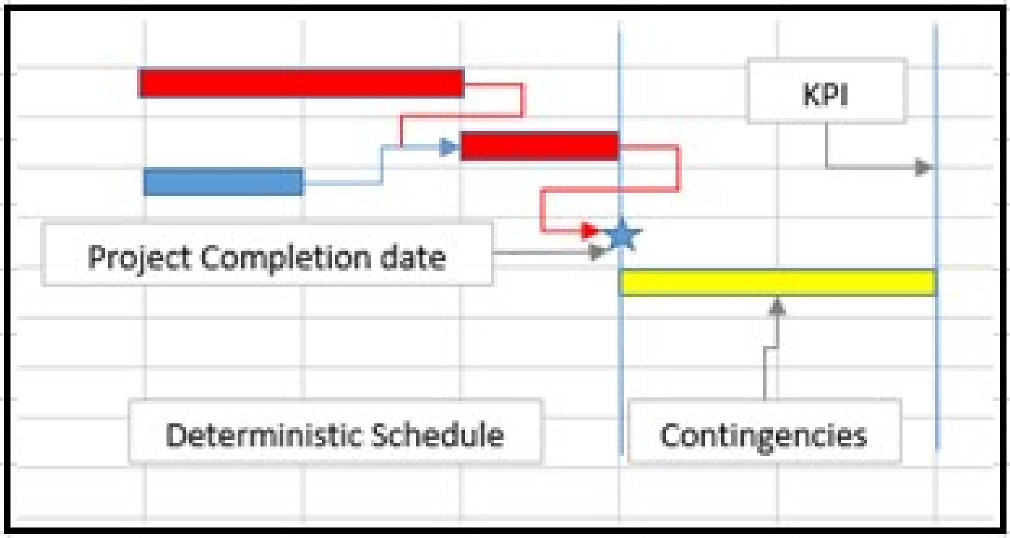


FIGURE 8-25 **Schedule Contingencies**

Schedule Contingency is a duration reserve for the identified risks.

- Schedule completion date: 11 Nov 15
- Schedule conservative date (P80): 28 Dec 15
- Contingencies = 47 days
- Date (P20) < Schedule KPI < Date (P80) ➔ 19 Oct 15<Schedule KPI < 28 Dec 15

Certain companies may define the acceptable likelihood range of success between P10 and P90 for their projects to determine a realistic KPI. Following the above rule and the project Bell curve, there is 90% chance to complete the project by 13 Jan 2016 resulting 63 days contingency reserves for the project.

- P10 = 30 Sep 15
- P90 = 13 Jan 16
- Contingency reserves to get 90% likelihood of success = 63 days
- KPI (the range between 30 Sep 15 to 13 Jan 16)

8.26. Schedule Conformance

The conformance index provides a means to assess how well a specific schedule model incorporates the guidelines, definitions, behaviours, and good practices for the components of the schedule. Lack of core required components mean non-conformance to the schedule practice standards. The schedule conformance index reflects where the weaknesses of the developed schedule model exist and the area's most in need of improvement. Schedule model conformance is assessed by evaluating the existence and effective utilization of the various components defined in the practice standard in accordance with good practice[PMI-Practice Standard for Scheduling, 2011].

PMI categorizes the components of schedule conformance to the following:

- The Core Required Components (CRC) as an obligation for schedule development
- The Resource Required Components (RRC) for resource loading plan
- The Earned Value Management Components (ERC) for utilising EVM
- The Risk Required Components (KRC) for schedule risk analysis

The requirement of the client is to develop a resource loaded plan including risk analysis. Therefore, total required components would be CRC + RRC + KRC and ERC would be considered optional. The total required components need to be fully utilized to achieve a minimum acceptable level of conformance. Scoring for the conformance index is carried out in accordance with PMI standards which divides the components into 3 categories.

- Core required components (CRC)
- Conditional required components (RRC, ERC, KRC)
- Optional components

Optional components are considered beneficial to improve the conformance index however should fully adhere to the definitions, behaviours, and good practice defined in the PMI standards. Schedules that are not fully utilizing all the required components will be considered developmental in nature [PMI- Practice Standard for Scheduling, 2011].

$$\text{Conformance index \%} = \frac{\text{Total number of earned points (Required + Optional)}}{\text{Total possible number of points}}$$

Where **0 < Conformance index % < 100**

EQUATION 8-5 **Schedule Conformance Index**

If the required components are not fully utilized, then the schedule model does not meet the minimum conformance. Minimum score would be 35 that comes from required components only as per standard practice table 8-47 [PMI- Practice Standard for Scheduling, 2011]:

TABLE 8-47 Maximum Number of Components by Category

Required	Conditional			Optional	Total Available
CRC	RRC	ERC	KRC	Optional	
36	11	9	7	40	103

A list of schedule components organized into core required components (CRC), conditionally required components (RRC, ERC, KRC), and optional components can be found in Appendix 2. The schedule will be assessed against the list of components in the appendix to count earned points (each required or optional component is equal to one point) as well as the conformance ratio.

In the ore care repair shop project, resource loaded schedule including risk analysis is one of the client requirements that shall be confirmed at the end of definition study phase. The project is in the planning phase and has not been entered to the execution phase yet. therefore, EVM components would be considered optional:

- Required (CRC, RRC, KRC)
- Optional (ERC)

A higher conformance index value does not automatically imply a better schedule model, however, it may indicate a greater likelihood of achieving project objectives.

The result of OCRS schedule assessment demonstrates the components of the plan incorporate over 92% of the standard guidelines, definitions, behaviours, and best scheduling practices.

The detailed calculation of the schedule conformance ratio is shown in Table 8-48.

Table 8-48 Project Schedule Assessment- Conformance Index

SCHEDULE ASSESSMENT WORKSHEET

Required	Conditional			Optional	Total
CRC	RRC	ERC	KRC	Optional	Available
36	11	9	7	40	103

Assessment Questions:

		Yes	No
1	Is there a requirement for resource loading?	X	
2	Is there a requirement to utilize EVM?		X
3	Is there a requirement to utilize risk management?	X	

The answers to the above questions will determine the values for the available points for the required and optional components to be placed in the fields below. The CRC is always required so additional required values from the chart above will be added to the CRC to obtain the total available required points. All remaining categories become optional by definition and that value is recorded as the optional value. The total available will always equal the value of 103.

Required Components Score

	Potential Available	Required	EARNED		
Core Required Components (CRC)	36	36	36	Required Points	54
Resource Required Components (RRC)	11	11	11		
EVM Required Components (ERC)	9	0	9	Earned Points	54
Risk Required Components (KRC)	7	7	7		
Total Required Components		54	54		

Optional Components Score

	Potential Available	Available Optional	EARNED		
Optional Components	40	40	36	Available Points	49
Resource Required Components	11	0			
EVM Required Components	9	9	5	Earned Points	41
Risk Required Components	7	0			
Total Optional Components		49	41		

Total Score

This box only completed if ALL required points are earned

Required Components Score	54
Optional Components Score	41
Total	95

Total Available Points: 103

Total Earned	95
Total Points	103

Raw Conformance Index Value	0.92
Multiply by 100	100
Conformance Index	92

8.27. Conclusion

A realistic functional schedule is the main core of the planning phase and is a key factor of project success. The project schedule should reflect the entire project scope, execution strategy, contract & procurement strategies, quantities, effort hours and project execution plan based on definitive estimates. Project schedule, a key output of the project time management must be accurate, reliable, enough detailed, well organized, and covered entire project scope of work & execution strategy to help management critical decisions.

The purpose of this chapter is to provide a clear understanding of the key factors in the schedule establishment for the Ore car repair shop project and its alignment to the proposed guideline.

The qualitative results of the OCRS practical schedule analysis can be summarized to the following items:

- The provided basis of schedule has a strong correlation to the other project management knowledge area and project core works. This document covers the project scope (Scope Management), required team, Stakeholders, and related strategies (Stakeholder/ Communication/ HR Management), Engineering efforts and strategies (Engineering Management), Construction/ Commissioning efforts and strategies (Construction Management), What if scenarios, Schedule Risks and its impact (Risk Management), Contract and Procurement strategies (Procurement Management), MTOs, Budget estimates, and project cash flows (Cost Management). Any variations to the project baseline plan shall be followed through the (Change Management) process.
- Any general policy on how to create a schedule, how to control the schedule, tools & techniques, software's, how to manage schedule changes, KPI`s, allowable thresholds, schedule performance criteria, schedule process description, updating process, accuracy level, type & frequency of schedule reports and provides a guideline on how schedule estimates have been stated in the schedule management plan and followed in this project.

- The OCRS project Schedule can be validated against the produced manual and standard scheduling practices by conducting a quality check for the following components:
  - ✓ Schedule WBS
  - ✓ Activity list
  - ✓ Activity description
  - ✓ Activity duration
  - ✓ Activity code
  - ✓ Activity logic
  - ✓ Leads and Lags
  - ✓ Constraints
  - ✓ Resources
  - ✓ Resource Calendars
  - ✓ Resource Breakdown Structure
  - ✓ Resource Histogram.
  - ✓ Project Calendars
  - ✓ Project major milestones
  - ✓ Project phase milestones
  - ✓ Total Float and Free Float
  - ✓ Weighting factor
  - ✓ Cost estimates
  - ✓ Periodic Funding limit
  - ✓ Critical path and Near critical activities
  - ✓ Progress Early and Late Curves
  - ✓ Contingency reserves

- ✓ Other attributes, like activity type, activity label, Cost Id, WBS Id, responsible person, location, and other related items shall be documented in schedule documentation.
- ✓ Schedule Baselines
- ✓ Area accommodation demands and availability
- ✓ Time based major commodity quantity report, earthworks, concrete, steel, cable, and…
- ✓ Cost and Time trade off practice to find the project optimum date
- ✓ Schedule risk contingencies and KPI

The quantitative results of the OCRS practical schedule analysis can be summarized to the following items:

- ✓ The Schedule Conformance Index (SCI= 92%) demonstrates the components of the conducted project schedule highly aligns to the standard scheduling guidelines, definitions, behaviors, and best scheduling practices.
- ✓ Project successfully delivered within the frozen timeframe and on budget. In addition, minor scope, time, and cost variations were recorded with almost no impact to the project schedule KPI
- ✓ Risks were successfully managed as only less than 40% of the contingency reserves were used to mitigate the identified risks
- ✓ Critical and Near Critical activities were managed successfully and No Schedule slippage was reported at the project closed-up phase.

9. CONCLUSION

In some developing countries there are no standard steps to define project study phase components particularly project management deliverables. Due to of this, the project management team defines its own unique way to carry out a project based on their traditional experiences and in most cases projects fail in meeting budget, time, and quality constraints.

This research provides a guidance list of the key project deliverables that need to be created, developed and validated throughout the study phase of the project. It can also be utilised as a comprehensive guideline to ensure all aspects of the project have been fully and comprehensively studied prior to the commencement of the execution phase.

9.1. Research Challenges

Conducting the research forming the basis for this thesis was very challenging as many organisations resisted disclosing information and data, in particular in projects that were considered to underperform or not meet KPIs.

In addition to the challenges in data confidentiality and access, collecting data from a group of construction and project management experts that cover a more diverse range of work experiences and professional background was a time-consuming exercise.

The norms & terminologies used by construction companies at the study phase contrasted across the industry and often did not align with any recognised project management standards.

To set up the study phase deliverables, no standard roadmap and procedures were found. Almost all mid-size construction companies and consultants in Iran used the requirements in the contract agreement as a reference only.

9.2. Summary of the central thesis statement

The focus of the research project was to review the standard project phases and deep investigation on the study phase development, process, and its key deliverables that are being used by leading construction/mining/ oil & Gas companies. Study development is a staged process where the projects progress in a controlled manner from the idea generation through to either:

- A state of readiness for project implementation and operation, or
- Closure and suspension of further development.

The key aims are to ensure that the study supports a robust business case and is subject to appropriate reviews and approvals as it progresses through development. All stages of projects however have a clear set of objectives at the start, a clear scope of work designed to achieve the objectives, and completion of the scope prior to a decision to progress to the proceeding phase. The following key activities must apply to all studies:

- Set up the key objectives
- Develop the work study plan
- Establish the study team
- Execute the study
- Develop the study deliverables, and
- Prepare and submit approval documentation

The study deliverables required for the identification, selection, and definition phases are usually provided in the form of study deliverables checklists in many leading construction companies. These checklists provide a tool for both establishing the required study deliverables and verification that the deliverables have indeed been produced prior to the next stage gate review. Stage gates are utilised at the conclusion of each phase usually representing full funding approval. To initiate a project, the following elements are required.

- A process for the identification, evaluation, and prioritisation in the capital portfolio.
- A stage gated project process based on the principles of clear deliverables and accountabilities for each project. These deliverables include activities and technical deliverables for each stage in a project's lifecycle.
- A review and approval process for progression of projects through each stage gate.

- A project management process to standardise methods and documentation for project evaluation and implementation.
- A suite of fundamental project management processes that apply throughout the project lifecycle.

The early stages represent a progressive increase in confidence in the technical, economic, and sustainable development parameters used to decide whether the project meets the specified business investment criteria. Once the criteria have been met and a decision has been taken to proceed with project implementation, the focus switches to detailed engineering, procurement, construction, and commissioning. In addition managing the process of project development requires the engagement of all stakeholders in order to set clear objectives, drawing up a well-defined scope of work, budget and schedule, and providing focused management to ensure that objectives are met.

The earlier stages are 'iterative' and may offer many alternate ways forward, each of which has to be evaluated before a final 'best' option is selected for detailed study. There are two distinct phases during the lifecycle of a project: project evaluation and project execution. Project evaluation or study phase (identification, selection, and definition) focuses on value generation whilst project execution focuses on value delivery and value protection. The following sections provide an overview and summary of study phases.

Project Initiation phase study is the initiation point for any project where the idea is established with stated objectives and expected benefits. Comparisons with similar projects can help to assess potential and guide future development. The project initiation process is very important in that it is the authorisation for work to commence on the project. The main key deliverable from the project initiation stage is project charter. If the project is approved to progress into the selection phase, a selection phase study plan is developed outlining the deliverables, resources, cost and schedule for undertaking the study. Project initiation key activities and the associated process map is shown at Figure 9-1.

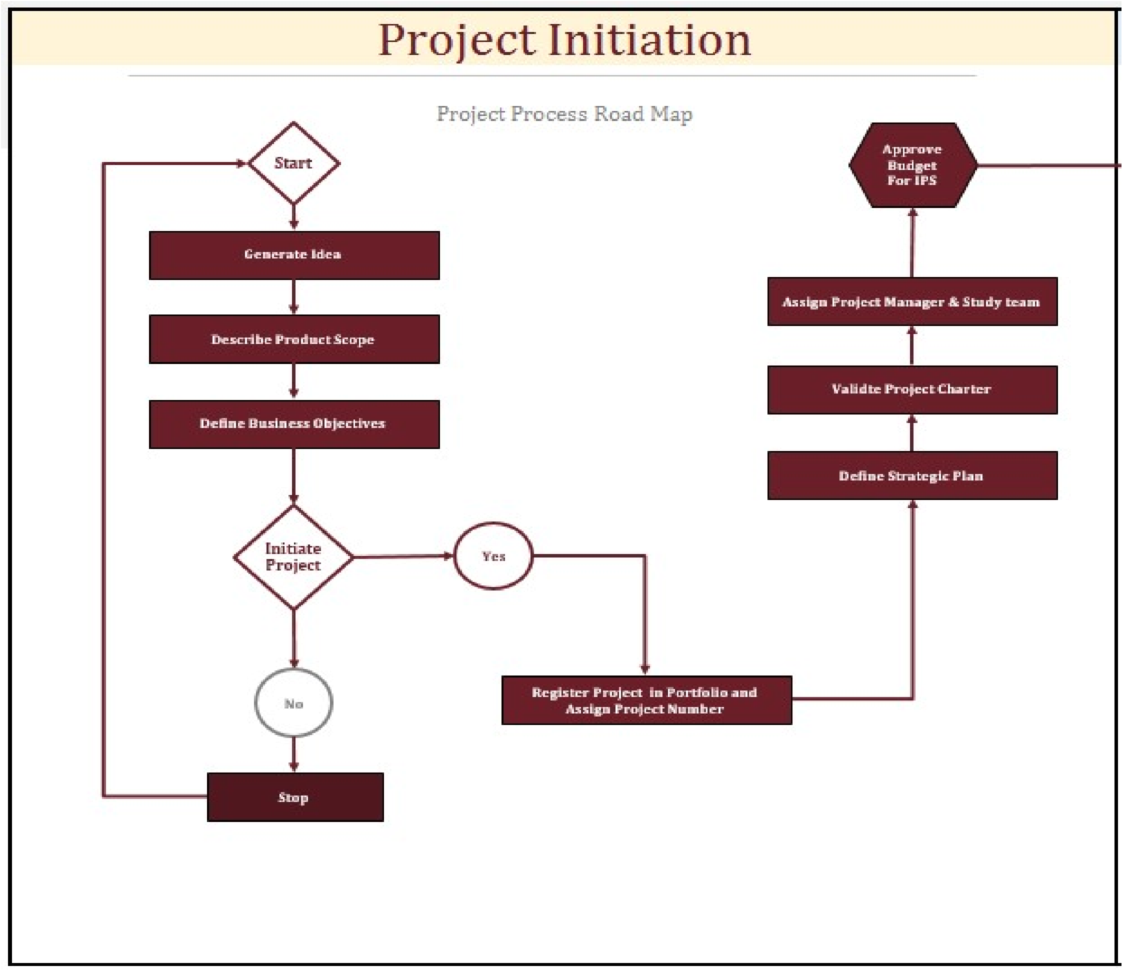


FIGURE 9-1 **Project Process Road Map – Initiation Phase**

Identification phase study is primarily to determine if a robust business case exists that justifies the project progressing to the next stage of development. It should clearly define the opportunity from a business case perspective, identify the key stakeholders, confirm the stakeholder requirements, and identify the range of credible options for further study and the criteria against which these options are assessed.

This process is fundamental to the success of a project and special attention should be paid to clearly defining the business objectives and strategic fit. Early in the identification stage, the selected opportunity is listed as a project for development and is put through a prioritisation process to secure placement in the short and long-term capital plans. Project identification key activities and process map is shown at Figure 9-2.

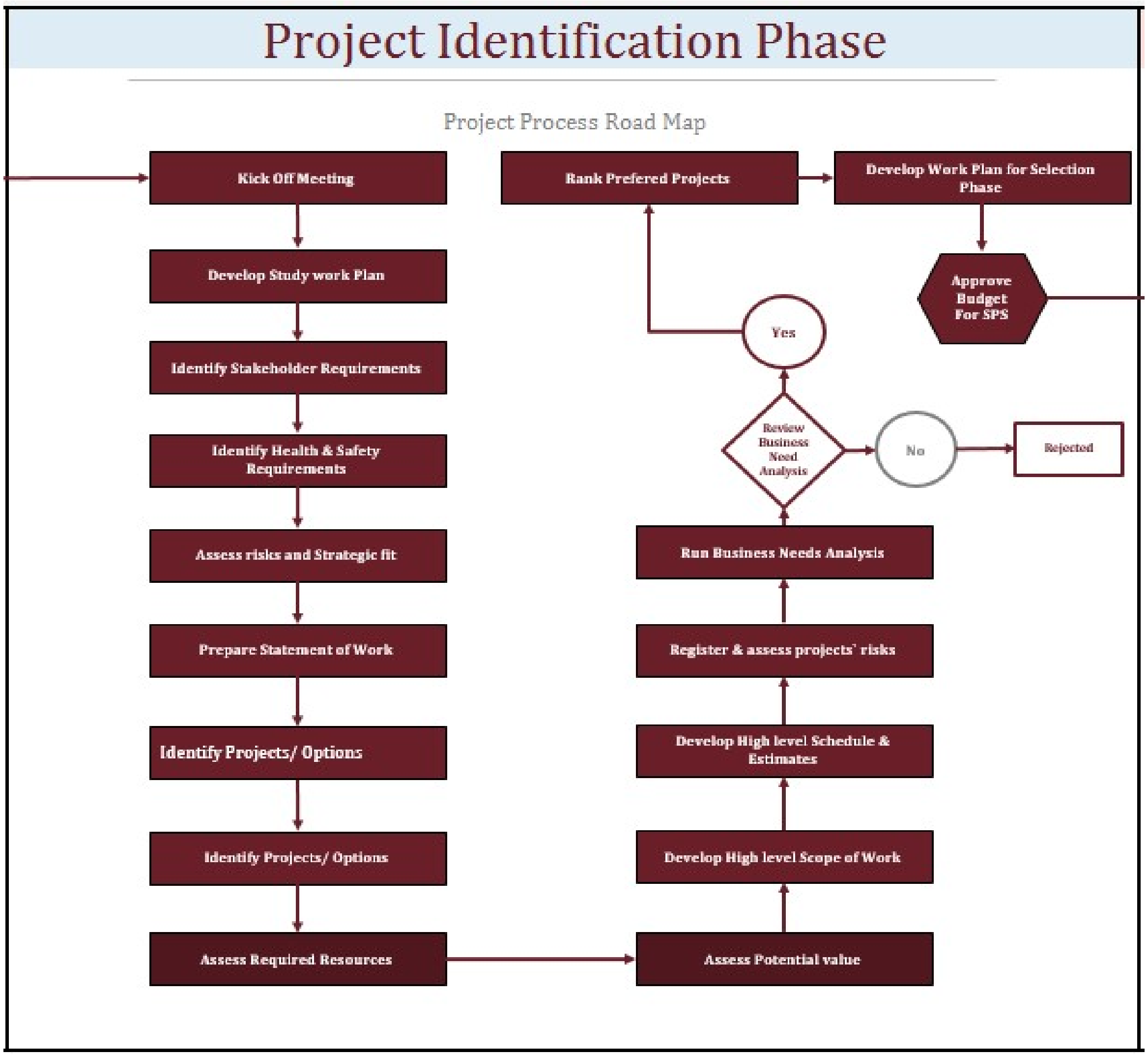


FIGURE 9-2 **Project Process Road Map – Identification Phase**

Key objectives:

- Validate business opportunity
- Identify all potentially viable options
- Compile stakeholder requirements
- Select options assessment criteria
- Baseline risks/opportunities, and
- Develop the Selection phase study plan

Value improving practices (VIP's) are techniques that improve the value of capital projects and will be run at this phase.

Selection Phase Study firm up the business case, investigate the various options that fulfil the business requirements, evaluate all significant risks, and select the option to proceed to definition study. SPS is a critical stage and is used to evaluate the viable technical options and to further finalise the project scope. The procurement strategy, contracting strategy, resourcing, accurate estimates & schedule, and DPS execution strategy should be completed by the end of this stage.

For each of the selected options, the project team develops the expected economic value, scope and a comparative estimate and identifies the associated risks and opportunities. At all times, through project evaluation the project team must maintain a focus on maximising value while using capital (and other resources) effectively. In addition, the project team also evaluates elements such as operability, maintainability, constructability and other VIPs, HSEC impacts, regulatory requirements, community impacts and any legal implications relevant to choosing the preferred alternative by the end of SPS.

Key objectives:

- Conduct project options assessment
- Select best option for carrying into DPS
- Confirm the technical viability of the selected option via an independent technical evaluation
- Update risks/opportunities, and
- Develop DPS plan

Key deliverables:

- Options identification and assessment worksheet
- Updated project risk register
- Technical evaluation report
- DPS plan
- Operational readiness plan
- Early engineering works usually up to 15% can be completed at the end of

SPS. The SPS engineering package is a key deliverable and includes items such as engineering reports, VIP reports, hazard study reports, drawings, specifications/datasheets, calculations, and design reviews including design for reliability, operability, and maintainability review

- Complete and verified SPS deliverables checklist, and
- Funding application for DPS and DPS report.

Project selection key activities and the associated process map is illustrated in Figure 9-3.

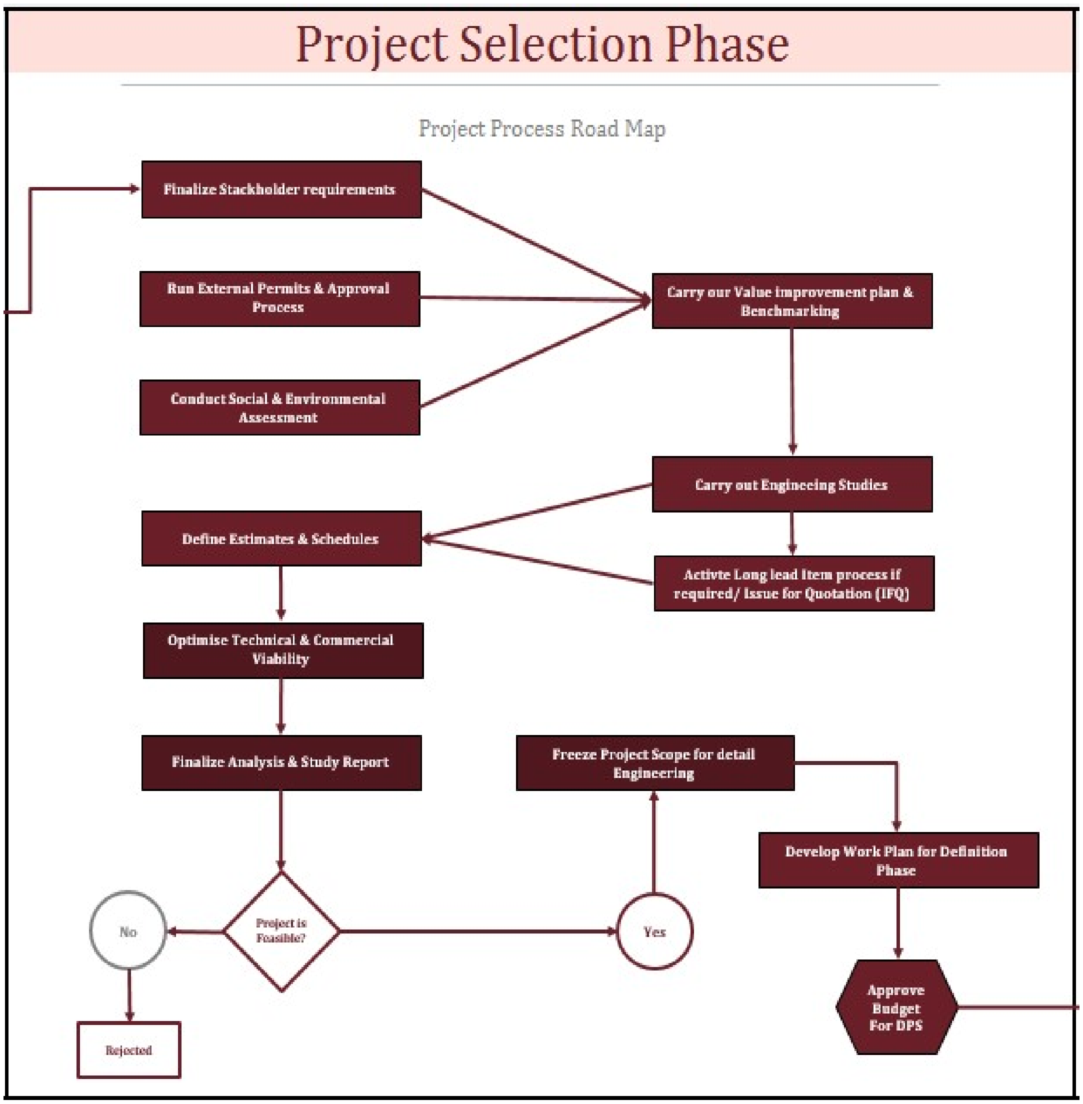


FIGURE 9-3 Project Process Road Map – Selection Phase

Definition Phase Study (DPS) comprise of engineering and optimisation of a single scenario, freezing and fully defining the scope, and fully developing the execution plans. This level of study is required for recommendation for project investment approval and should include a comprehensive financial evaluation and full risk analysis. Estimates and economic analyses are refined to an acceptable level of accuracy. The purpose of the DPS stage is to confirm the business case for the problem or opportunity, supported by the scope of the preferred alternative, a PEP and a detailed execution schedule (central estimate and resourced schedule).

Key objectives:

- Freeze scope with selected final option and finalise project execution plan
- Complete basic engineering package includes items such as engineering reports, VIP reports, hazard study reports, drawings, specifications/datasheets, calculations, and design reviews.

Key deliverables:

- Basic design/engineering package
- Updated project risk register
- Project execution plan
- Project operational readiness plan
- Lessons learnt register
- Complete and verified DPS deliverables checklist, and
- DPS report. The DPS report is the key deliverable of the DPS and it summarises all the outcomes of the study.

Project definition key activities and process map is shown at Figure 9-4.

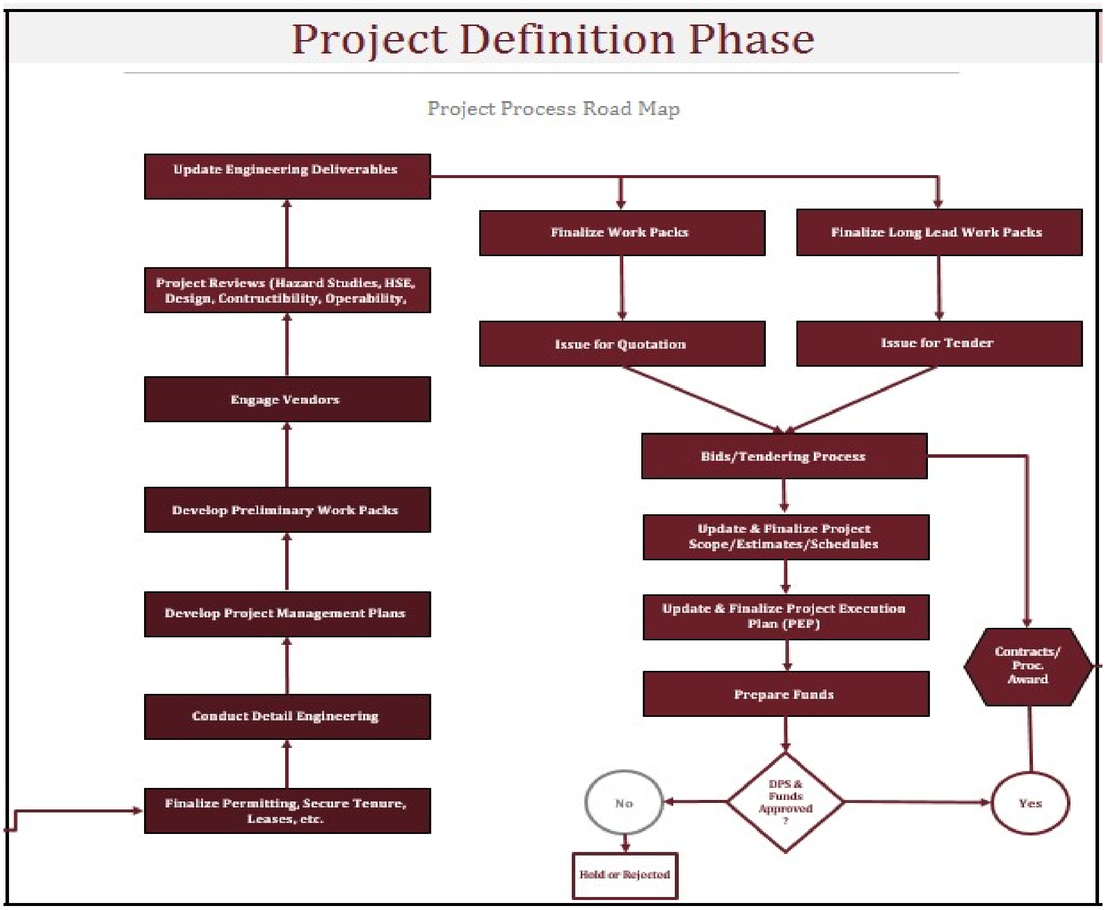


FIGURE 9-4 **Project Process Road Map – Definition Phase**

Project Execution phase encompasses detailed engineering, procurement, construction, pre-commissioning, and commissioning of the project as per the approved PEP. The key outputs of the construction, and commissioning & ramp up stages include substantially completed facility, as-built drawings, punch list and certificates of substantial completion, implemented project, trained operating personnel, care, custody and control transferred to operations.

In addition, the following steps are expected to be carried out during the commissioning phase:

- Pre-operational verification
- No load commissioning
- Load commissioning

- Care, custody, and control, and
- Performance verification

Project Closeout is the final stage for each project. The objective of this stage is to finalise all contractual obligations, provide both a record and critique of all events and activities over the course of the project, including lessons learnt, and formally close the project. While project close-out is defined as the final stage in the lifecycle of a project, close-out processes are implemented throughout the project stages.

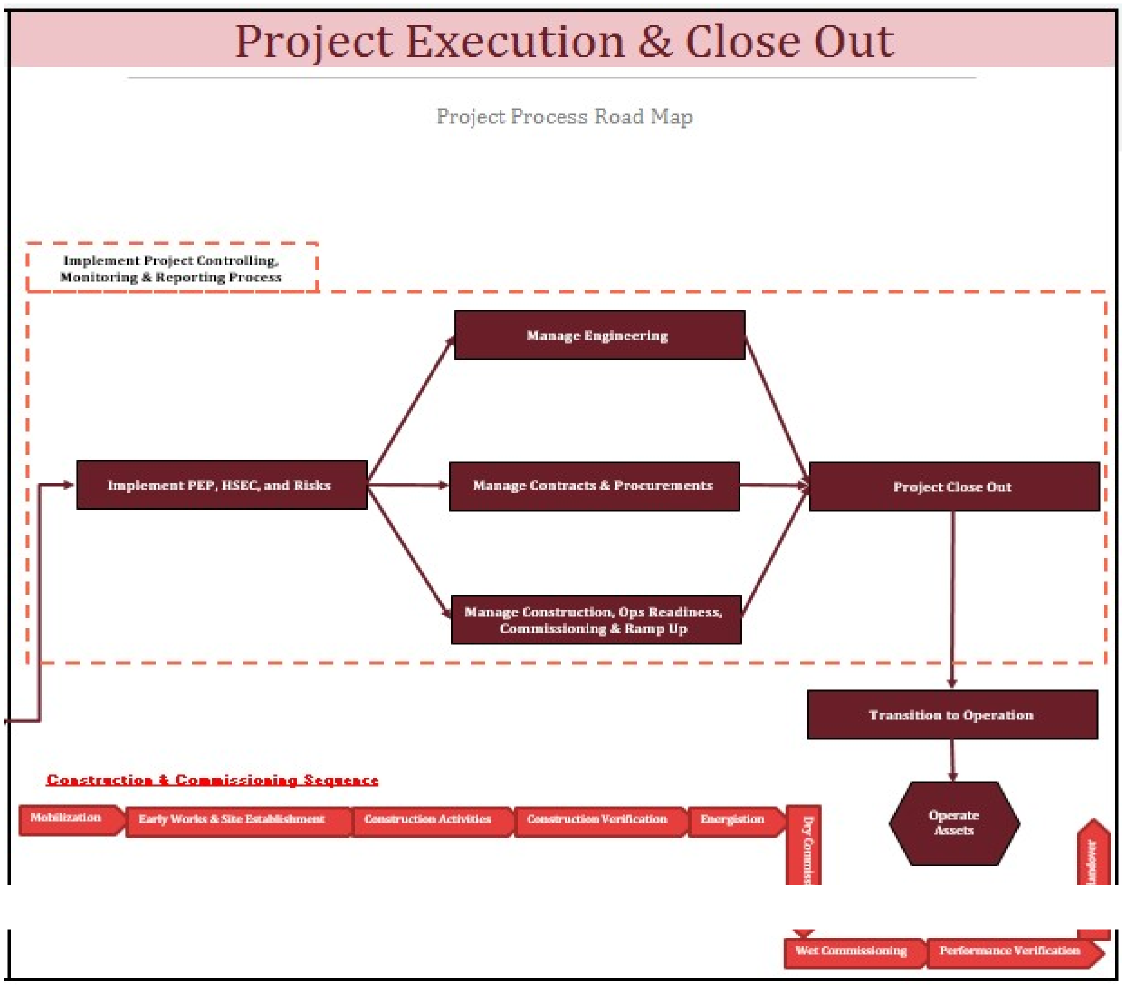


FIGURE 9-5 Project Process Road Map – Execution Phase & Close out

Figure 9-6 represents the summary list of mandatory deliverables throughout the study phase of project.

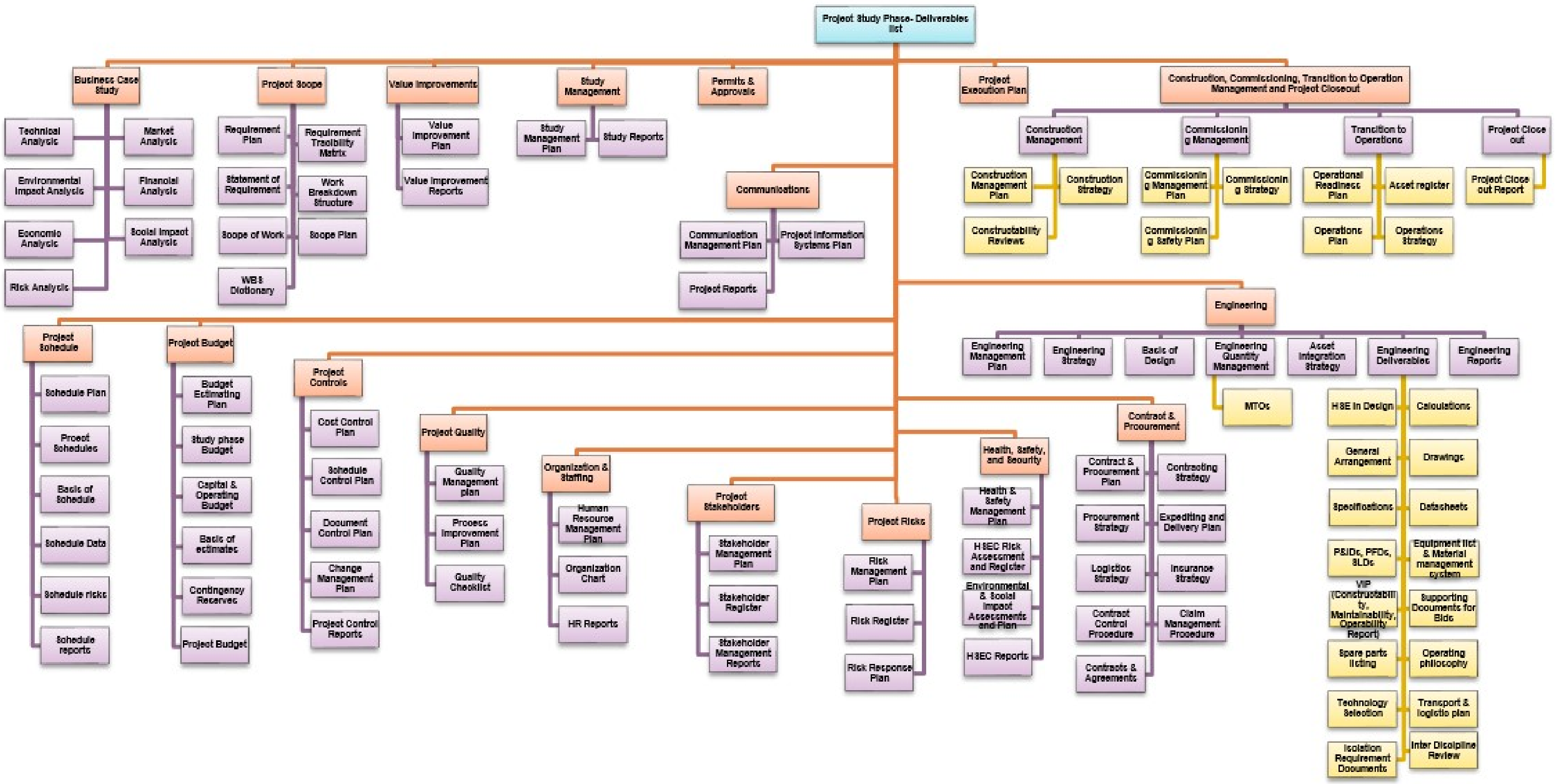


FIGURE 9-6 **Project Study phase Deliverables**

9.3. Research outlines and findings

In this research, we investigated the industry`s most relevant practical references and project management standards applied by lead construction/ Oil & Gas/ and Mining companies by focusing on the following areas:

- Various principles, frameworks, and process of study phase development by organisations and projects
- Nonconformity of the project deliverables to the project management standards
- Various definition, terminology, and classification of study phase reports (e.g. certain companies use the terminology "contingency reserves" resulting the impact of the IDENTIFIED risks and other companies also capture UNIDENTIFIED risks within this nomenclature)
- Incomplete conduction of the project study phase and incomplete deliverables
- Lack of professional project management knowledge in middle level project management
- Project schedules and budget estimates at study phase are being developed without any formal basis or justification. For example, to develop the schedule, it is essential to consider the project contractual requirements, quantity of works, resource availability, production rates, contract strategy, construction & commissioning strategy, fund limits, risks, and other related parameters.

As a result of this section, heavy focus was placed on project management standards, reviewing existing procedures & standards used by lead Oil & Gas and Mining companies throughout the world and extracting a common framework for the study phase development implemented in successful projects. The outcome of this research can be applied as a template, guideline or manual by organisations to conduct comprehensive studies accordingly.

9.4. Summary of the central thesis statement

This research ultimately has various benefits for key project stakeholders in construction industries such as:

- Increases project team awareness on the key components of the study phase deliverables
- To ensure accurate investment and minimised risk prior to the execution phase
- To aim engineering consultants to establish comprehensive documents/deliverables at study phase rather than following their traditional methods
- To assist project managers/planners/decision makers to perform more effective project planning at the study phase
- To improve the project effectivity and efficiency at the construction phase. In addition, realistic project performance and productivities are expected
- To minimize construction delays and project cost overruns by population of adequate study deliverables
- A significant improvement to the organizational culture in some developing countries by implementing a robust methodology & procedure to run the project study phase
- To be used as a standardized template for consultants to assess the quality of the study phase deliverables
- To minimize the rework and study costs by setting up the clear study definition, required deliverables list and key components
- To provide a framework describing a structure to ensure the appropriate level of deliverables are provided to select, develop, and execute projects in a safe, efficient, and effective manner. The framework encourages the completion of key elements and deliverables prior to the decision to continue to the next stage
- To provide a baseline against which review/assurance activities can be conducted
- To ensure projects are continuously evaluated through the stage gated process and to ensure resources and capital are utilised appropriately
- An case application on project schedule development - Chapter 8, can be considered as one of the industries 'best practice' in time management covering full analysis incorporating the impact of the project risks, quantities & efforts, project budget,

frozen scope & contractual requirements, stakeholders, communications, contract & procurement strategies, execution strategies and other relevant project parameters

9.5. Recommendation for future research

The following areas are recommended for further investigation and research:

- Study phase deliverables and its key components can be expanded and standardised to all different type of projects other than construction projects (e.g. IT & research projects)
- Other planning and scheduling techniques like PERT (Program Evaluation and Review Technique), GERT (Graphical Evaluation and Review Technique), LOB(Line of Balance), CCPM (Critical chain project management), and LSM (Linear Scheduling Method) can be further investigated as per project requirements.
- The impact of project study deliverables to the project scope, time, cost, and quality can be quantified and conducted separately if companies permit prospective researchers to have access to the project detailed data and results.
- A comprehensive template and checklist can be generated for the study phase development supporting companies to assess the maturity level of the provided deliverables, and provide a 'health check' to projects prior to execution.
- Similar to the schedule development practice in Chapter 8, a similar exercise can be conducted for project scoping, budgeting estimates, risk analysis, quality planning & controls. All project management knowledge areas can benefit from the feedback of successful projects implemented by leading companies.
- A functional software/programme can be developed to reflect the full list of mandatory deliverables & key components as well as a step by step work instruction to progress the project study phase. This will assist project managers to ensure project study deliverables are fully performed by engineers.

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APPENICES

Appendix 01: SESPA Process

ANNEXURES

ANNEXURE 1: The *SESPA* process as described by *BOC*

WHY SESPA ?

INTRODUCTION

SESPA™ is the core of BOC's global supply selection strategy. It has been developed and used uniquely by BOC for evaluating and selecting 'best in class' suppliers and monitoring their performance over time.

THE PRINCIPAL BENEFITS OF SESPA™ ARE:

It provides a consistent and structured approach to the selection of suppliers.

SESPA™ is applied by a crossfunctional team so decisions are agreed and jointly owned.

SESPA™ provides the structure to guarantee that decisions on our requirements and the subsequent successful supplier are reached with agreement.

Evidence and justification of the final decision is available.

Once a decision is reached, SESPA™ forms the basis for continuous improvement by providing the criteria for on-going measurement of the supplier.

APPLICATION OF THE SESPA™ PROCESS

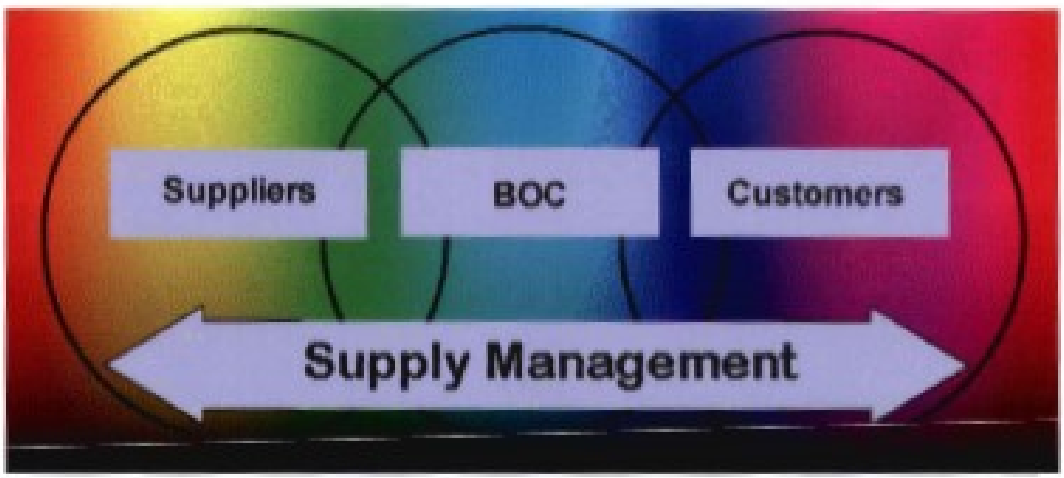
SESPA™ should be applied consistently for

- Products which are critical to the business
- High dollar value contracts
- Emotive decisions where it is important to have cross functional input, evidence and justification of the final decision

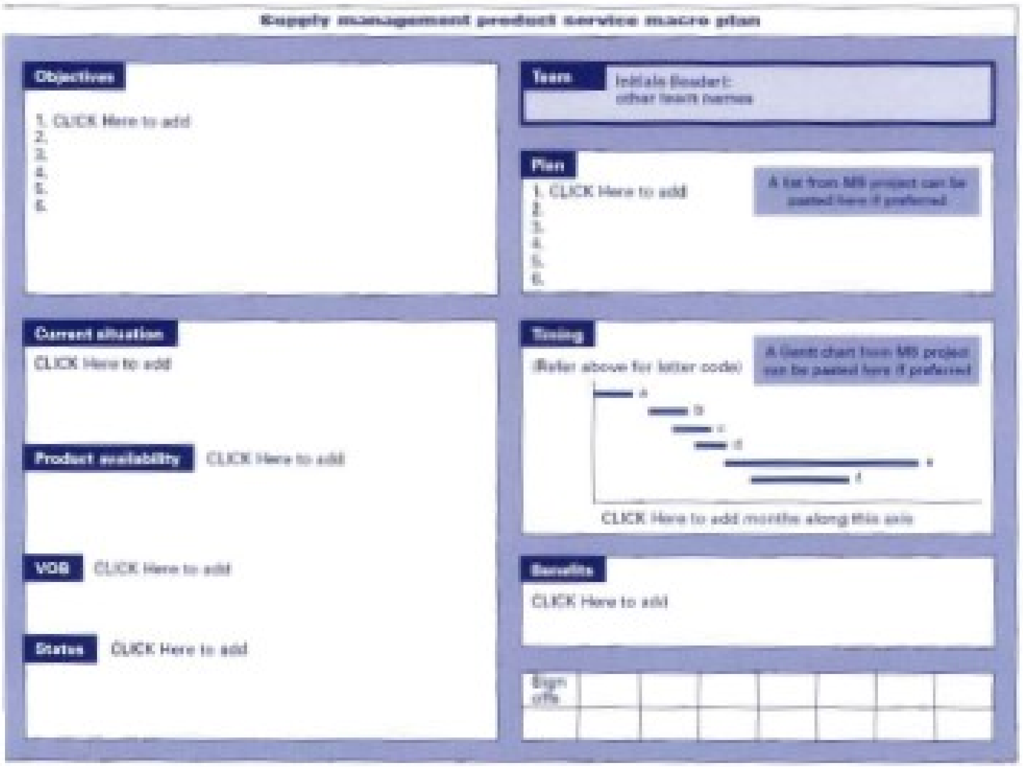
SUPPLY MANAGEMENT SERVICE OFFER

Supply Management predominantly take on a facilitation role in the SESPA™ process.

It is their responsibility to ensure that the business gains the maximum benefits from the supplier evaluation and selection and the on-going relationship with the successful supplier.



ANNEXURE 2: Macro plan template



Appendix 02: PMI Schedule Components List

Project Start Constraint					O	
Activity Label	R					
Unit of Measure	R					
Activity Original Duration	R					
Activity Remaining Duration	R					
Activity Actual Duration	R					
Activity Total Duration	R					
Project Remaining Duration	R					
Project Actual Duration	R					
Project Total Duration	R					
Activity Effort/Work					O	
Activity Work Percent Complete					O	
Finish to Start	R					
Start to Start					O	
Finish to Finish					O	
Activity Early Start Date	R					
Activity Late Start Date	R					
Activity Actual Start Date	R					
Activity Resource Leveled Start Date					O	
Project Early Start Date	R					
Project Late Start Date	R					
Project Actual Start Date	R					
Project Resource Leveled Start Date					O	
Activity Early Finish Date	R					
Activity Late Finish Date	R					
Activity Actual Finish Date	R					
Activity Resource Leveled Finish Date					O	
Project Early Finish Date	R					
Project Late Finish Date	R					
Project Actual Finish Date	R					

Project Resource Leveled Finish Date					0	
Total Float	R					
Free Float	R					
Critical Path	R					
Activity Physical Percent Complete	R					Activity percent complete must be either physical OR duration - ONE is required
Activity Duration Percent Complete						Activity percent complete must be either physical OR duration - ONE is required
Project Physical Percent Complete	R					Activity percent complete must be either physical OR duration - ONE is required
Project Duration Percent Complete						Activity percent complete must be either physical OR duration - ONE is required
Activity Code					0	
Activity Cost Category					0	
Activity Cost Estimate					0	
Activity Resource Actual Quantity		R				
Activity Resource Total Quantity		R				
Project Resource Actual Quantity		R				
Project Resource Total Quantity		R				
Activity Scope Definition					0	
Finish Not Later Than					0	
Project Finish Constraint					0	
Custom Field					0	
Earned Value			R			
Planned Value			R			
Activity Actual Cost (AC)			R			
Cost Performance Index (CPI)					0	
Schedule Performance index (SPI)					0	
To Complete Performance Index (TCPI)					0	

Activity Most Likely Duration				R		
Activity Optimistic Duration				R		
Activity Pessimistic Duration				R		
Activity Cumulative Probability Risk Distribution				R		
Probability Risk Distribution				R		
Summary Activity					0	
Variance					0	
Number of Components in Category	36	11	9	7	40	NS items are not counted in OPT

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PMI Schedule Components List

PUBLICATIONS

Rad, S., Nikraz, N., (2017). Practical schedule range analysis. International Symposium for Production Research 2017, 13 – 15 September 2017, Vienna

Component	Paper 1
Conception and design of the research topic	a, b
Background and literature review	a
Experimental design – content analysis	a
Experimental design – semi-structured interviews and ethic clearance	-
Acquisition of data and method	a, b
Data conditioning and manipulation	a
Data management, analysis, and statistical method	a, b
Data Inventory and Modeling	-
Microsimulation and lifecycle impact modelling	-
Interpretation and discussion	a
Paper writing and preparation	a, b
Paper adjustment, editing and proofreading	a, b
Final approval	a, b

We, the co-authors endorse that the levels of contribution indicated above are appropriate.

Author name	Attribution key	Signature
Sam Rad	a	
Navid Nikraz	b	