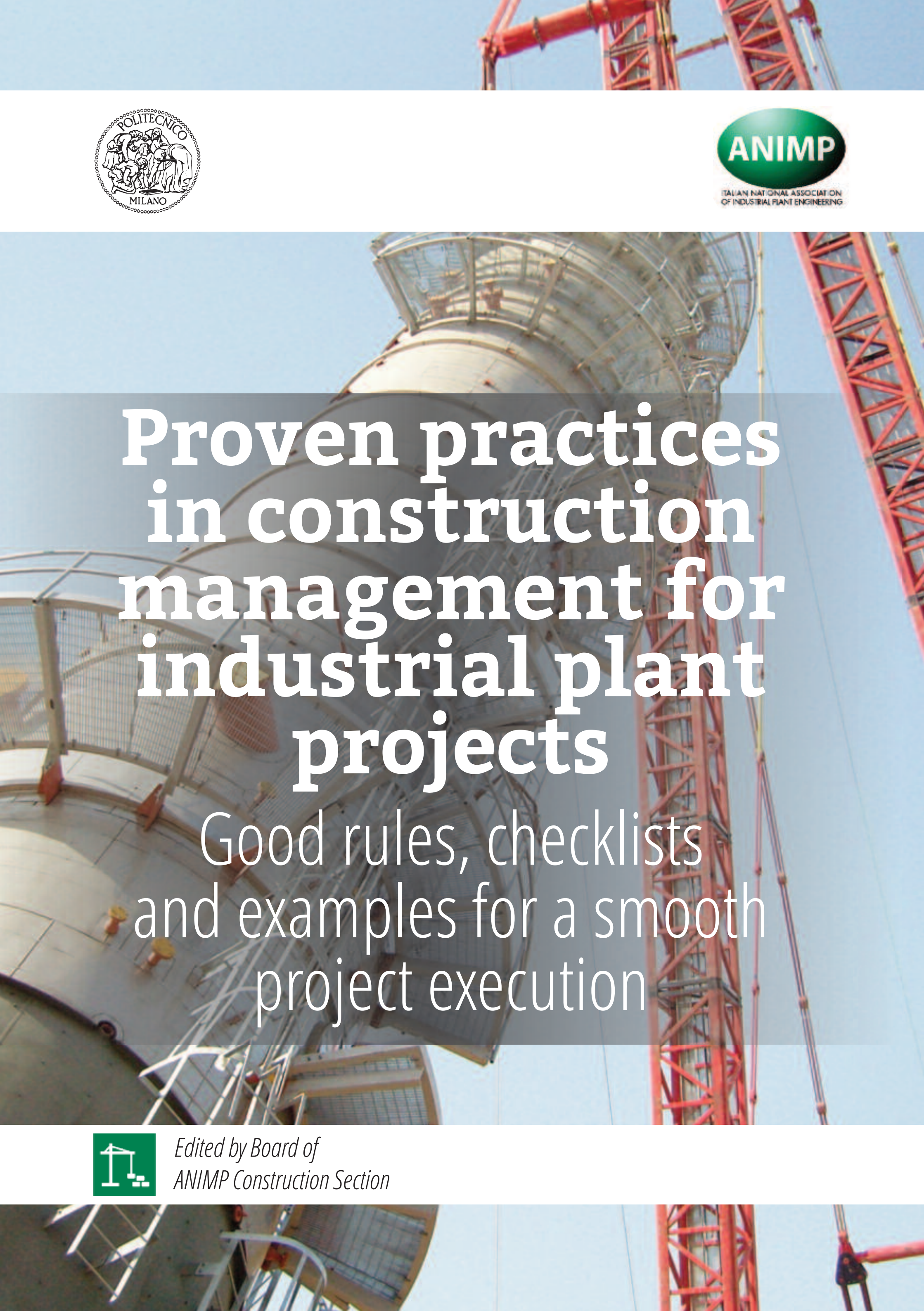


POLITECNICO MILANO

ANIMP
ITALIAN NATIONAL ASSOCIATION OF INDUSTRIAL PLANT ENGINEERING

Proven practices in construction management for industrial plant projects

Good rules, checklists and examples for a smooth project execution

Edited by Board of ANIMP Construction Section

ISBN 9788888198385

September 2015, Milan - Italy

Welcome

I'm proud to introduce the second volume of a series aimed at boosting innovation and at capitalizing lessons learned in the Engineering and Construction Sector.

ANIMP's main mission is to support the sharing of Industrial Plant culture all over the world

through its technical chapters that merge the experiences in the specialist disciplines of the Associated Companies and Italian Universities.

The over mentioned collaboration between Industrial Companies and Universities in Industrial Plant engineering and management sector is efficiently and practically expressed by this initiative of the ANIMP Construction Section that proposes a reference for spreading and divulging industrial plant culture and best practices.

Special thanks go to: Mauro Mancini (and his team) for coordinating the editing process, Angelo Zucconi, for being the main source and inspiration of this book and "last but not least" ANIMP's Board of Construction Section for their high technical contribution that made possible the issue.

I hope that this book will be the basis for the future generations of Construction Managers and that this type of initiative will drive the future challenges of the Association.

Claudio Andrea Gemme

(President of ANIMP)

Credits and acknowledgements

It is surprising that in less than a year a second White Book of the ANIMP Construction Section has been published. The story of this book is completely different from the previous one (Advances in Plant Modularization, ANIMP, 2014) except for the real origin and strength of the publication: the experience and knowledge of the authors (more than 250 years of experience in different branches and Companies operating in the Construction Management sector).

The story behind this book started from several documentations produced by Angelo Zucconi to whom my gratefulness is addressed both as ANIMP representative and at a personal level. Angelo worked actively for more than 20 years in ANIMP, always driven by his passion and deep knowledge of Construction Management. Angelo's previous productions were the basis for huge discussions and meetings of the Board of the Construction section (generally starting in the afternoons continuing until midnights) where participants, in a perfect passionate "Italian style", shared their own knowledge, experience and hours to write even just a single concept.

I personally learnt a lot in these fruitful discussions mainly based on experiential knowledge but also always aiming at including the point of view of the international academic community.

The title and subtitle synthetize perfectly the content: the word "proven practices" has been preferred to the more common used "best practices" since the presented practices come from real experiences. Disclosing these practises, we perfectly know that the future will surely change and that we will need to continuously review and adapt our approaches to the real and contingent context of our projects. This book aims to be a handy support exactly in this direction: it is addressed to practitioners, due to the important presence of real data and tools for a "plug and play" usage in their companies, and to neophytes, given the global picture of the topic.

The Authors of the book are: M. Bernoni, P. Cremonini, M. di Gennaro, G. Franco, G. Gariboldi, G. Giancane, G. Gioviale, M. Mancini, M. Spongano, A. Zucconi. ANIMP financed the activity including graphic setting, printing of the volume and distribution of the hardcopies. Involved Companies supplied pictures, reported documents and involvement of their technicians and manager for content development.

At the end my warm gratefulness is for each member of the Board of the Construction Section (mentioned with their affiliation at the end of the book), their colleagues and all master students and temporary researchers of the Politecnico di Milano involved back office (with particular mention to Alberto Piana and Agnese Travaglini).

Prof. Mauro Mancini

(ANIMP Construction Section Coordinator)

Preface

I am honoured to explain how my contributions to this booklet have been influenced by most of the experiences in Construction achieved as Site Construction Manager in an EPC Contractor company.

I am referring to my work in Snamprogetti, now included in Saipem, in Construction sites in countries like Argentina, Bahamas, Canada, Nigeria, Wales and of course Italy. These experiences have been very significant due to the contribution of Senior Construction Managers leading Construction Contractors organizations who were active on sites where I was working.

Site experiences gave me the possibility to become Snamprogetti Home Office Construction Manager and to introduce in this organization operating instructions and parameters, which are still in use. In particular, I would like to mention the Construction Standard Man-hours.

Then I gave life to Serding Company and, entering in ANIMP, I have been active in the Construction Section and later on, as member of ECI as well, I was coordinator of the ANIMP- ECI Regional Unit. Utilizing all the experiences and ideas achieved I am teaching in ANIMP courses and in Masters courses organized by MIP (the Business School of the Politecnico di Milano). These are fantastic opportunities to be in touch with managers and technicians of the new generation interested in Construction matters.

These are my personal facts and activities, which are underneath part of the content of this publication.

At the end, it is with emotion and joy that I recognize in this booklet a condensate of my professional life and so I am grateful to have been called to cooperate with the team that has produced this publication.

I wish for everybody the possibility to find in this publication cues for reflections and starting points to introduce new ideas in the projects execution, in line with the present possibilities offered by modern technology.

Angelo Zucconi

(Serding CEO)

Index

1 | Introduction

The main topics of this book are proven practices in Construction Engineering activities to properly develop a Plant Project in Oil & Gas sector. On one side, the term proven practice (respect to the more common "Best Practice") describes the origin of the book that is the experience of the members of the ANIMP Construction Section. On the other side, giving that the knowledge at the very base of this book relates directly on the Oil and Gas Sector, the previous assumption cannot be considered 100% appropriate, the limitation to the Oil & Gas Projects seems too strict since most of the subjects are applicable to a larger field, such as Industrial Plants in general.

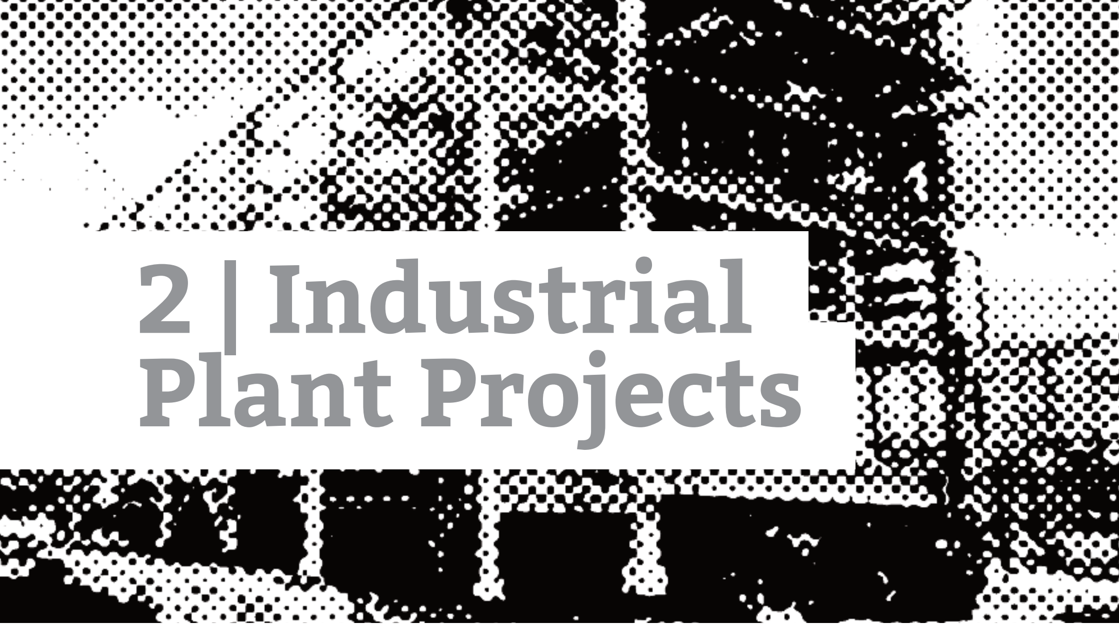
Any extension to other sectors has to be carefully evaluated before declared as applicable.

Moreover, this book does not cover all the Oil and Gas Projects typologies. Off Shore Projects, Pipelines and sea lines are not considered.

The Oil and Gas Projects normal conditions considered here are the ones where there are unimportant limitations to the extension of the area involved.

The experiences have been collected from companies like the EPC Contractors who, in executing projects, take care of the Design (called Engineering) and Procurement phases, which are, along with the Construction, the important phases of a Plant Project.

Combination and harmonization of the Engineering and Procurement phases with the Construction one are the key factors for a successful Project.



2 | Industrial Plant Projects

2.1 Projects Today

The evolution of Oil and Gas Projects has fostered the awareness about and the development of better standards in terms of:

- Health, Safety and Environment (HSE) risks reduction during and after project execution. A proper definition of 'risk' regarding safety matters can be found in the article "On the new ISO guide on risk management terminology" (Terje Aven, 2011);
- Sustainability, Local Content and attention to local communities during and after the Construction phase;
- Overall technical, economic and financial performances.

Focusing on Construction activities, they have been, and still are, subject to a continuous evolution as well. This evolution is enhanced by contributions coming from both internal and external sources. A valid example is represented by the logical improvement achieved thanks to the lessons learned process, as further mentioned in chapter 11.

Through the years, the Construction activities have also been burdened with stricter regulations mainly concerning labour, personnel employment and the use of the land.

A Construction activities peculiar aspect is that, in daily Construction Management, there are so many unplanned situations to be tackled, that nobody has the ability to forecast the best solution for all of them. Nevertheless, suggestions made in this book, produce value when Construction planning is in place.

All Construction activities can be seen as a carefully detailed and organized operation where last minute decisions should be taken by a well-experienced team headed by a professional Construction Manager.

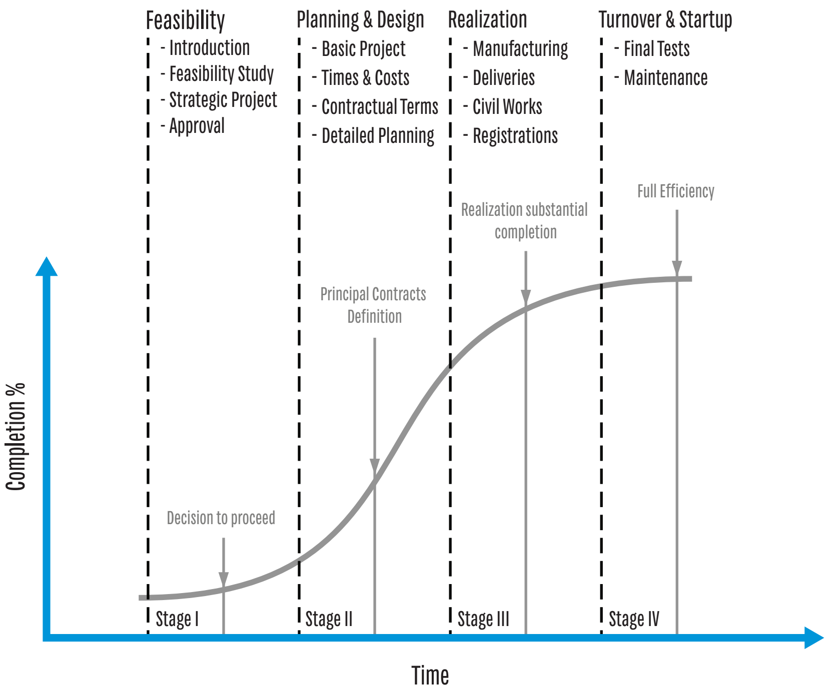
2.2 The Project Life Cycle

Every Project has many parents. Their Sponsor is called "Client", "Owner" or "Customer".

The birth of a Project can be a very long process that in some cases even lasts dozens of years.

It is initially fed by intuitions. These intuitions must be then tested through the so-called Feasibility Studies, which may be produced with Consultants help. Feasibility Studies strive to find the best solution, especially in terms of amount of capital to be invested.

The final step is the "Front End Engineering Design" (FEED). This document contains esteems of all EPC phases. It has to be approved by all concerned Parties and sustained with enough financial resources.



[Figure 2.1 - **Project Life Cycle: from feasibility studies to startup (Siirtec Nigi)]**

The birth certificate of a project can be considered ready after the Client agrees upon all terms, including the responsibility to execute the project.

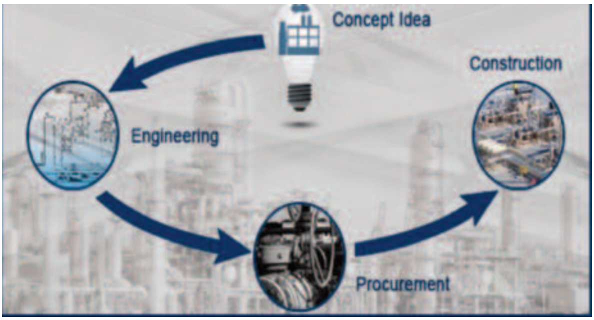
The next step is looking for an EPC Contractor capable to handle the execution phase.

The EPC Contractor choice is crucial to ensure the well-being of a project. Most clients, when it comes to this point, trust themselves with techniques that have been proven successful in the past, without any systematic analysis. The article "A Supporting Tool for the Rational Identification of Contracting Strategies for Complex Projects" (Olimpia Loiacono, Jorge Corredor Botero, 2015) presents a possible methodology to better drive the choice process.

The decision to go ahead with the Project is challenged by indications coming from all the parties involved as well as from the bidders. The Client, at this stage, still has the faculty to change part of the FEED. He can also suspend the Project with minimum money loss.

2.3 The Project Execution

Once the Client has assigned the project to the awarded EPC Contractor, the execution phase begins. The Client itself constantly supervises every step of the project (represented in Figure 2.2).



[Figure 2. 2 - **EPC Phases Overivew]**

Usually, in Oil and Gas Projects, the proportion between the 3 EPC phases, in terms of investment, is:

- Engineering 5-15%
- Procurement 40-60%
- Construction 30-50%

On the other side, in terms of time, the 3 phases have to overlap as much as possible (see Figure 2.3). This approach is called "Concurrent Engineering" or "Fast Tracking". Its importance is well described in the article "Overlapping design and construction activities and an optimization approach to minimize rework" (M.A. Hossain, D.K.H. Chua, 2014).

[Figure 2. 3 - **EPC phases "Concurrent Engineering" or "Fast Tracking" approach]**

This overlapping is very difficult to describe in a unique way, since Construction is usually considered completed when "Mechanical Completion" is achieved ("Pre-commissioning" activities are included as well), but each company can have a slightly different view and definition of this point.

After that, it follows the "Commissioning" phase (see Figure 2.4). Even this phase is carried out according to the previously mentioned overlapping approach. "Commissioning" ends with the "Start Up" of the Project, which can now be referred to as "Plant". Once "Start Up" is accomplished, the Plant finally becomes operational.

[Figure 2. 4 - **Commissioning phase overlapping approach]**

Moving from Construction to Commissioning is a very critical step. It's usually carried out system by system, in order to obtain the smoother transition possible. Among all the resources required for the Commissioning Phase, Process Engineering is one of the most important, especially at this stage.

2.4 The Stakeholders

Up to this point the book mentioned the essential parties involved in a Project execution such as:

- Clients;
- Consultants;

- EPC Contractors.

Instead of subcontracting all Construction activities, it is possible to turn to partial or full Direct Hiring.

If proceeding like this, the Client has to fulfil all uncovered EPC Contractor functions resorting upon internal resources.

Other examples of Project responsibilities partitions accounted for are:

- EP Contractors taking only care of Engineering and Procurement;
- EPCS Contractors (where CS stands for Construction Technical Supervision);
- PM Consultants (where PM stands for Project Management).

Construction Contractors can be classified as "General" Contractors or "Discipline" Contractors such as Civil, Building, Mechanical, Piping, Electrical, Instrumentation, Insulation, Painting, Fire-proofing, etc.

Considering an EPC Contractor project organization, members of the last group can be also referred to as Sub-Contractors. They are, in fact, accounted for various discipline or sub-discipline such as piling, buildings, sewers, underground piping, piping prefabrication, supports, small-bore piping, transportation, warehousing, lifting, etc.

For some disciplines, like buildings and tanks, the EPC Contractor may even decide to subcontract the relevant scope on an EPC basis.

In industrialized countries, Power Units and Steel Structures Suppliers may be requested to provide the installation of their components as well. In these cases, though, it raises the risk of claims coming from other Mechanical Sub-Contractors. Delays may in fact most likely occur in their work.

Specialized services may be furnished by Third Party Agencies/Suppliers (ready mix supply, laboratory testing, Non Destructive Testing –NDT-, Post Weld Heat Treatment –PWHT-, chemical cleaning, etc.).

All these solutions can be combined in several ways. Each one has different risks and different management strategies. In the early stages of a project the subcontracts/service providers number and mix, present on site, should be well evaluated. Too many parties involved can create potential contractual conflicts and disputes as mentioned before.

Further details on stakeholder management strategies are addressed in the article "Stakeholder management in construction: An empirical study to address research gaps in previous studies" (Jing Yang, Geoffrey Qiping Shen, Manfong Ho, Derek S. Drew, Xiaolong Xue, 2011).

2.5 Types of contracts

All the above-mentioned parties are bound together with different types of contracts, which can be classified based on the materials and services supplied.

For example, EPC Contractors can sign a “Turn Key” contract, where the Client receives the Plant fully operational or a “Mechanical Completion” contract, where the Client has to take care of the Commissioning phase by itself.

EP Contractors sign contracts, which only include Engineering and Procurement. Usually they provide Construction Supervision too during the Project execution carried out by Construction Contractors.

Most common contract forms are:

- Lump Sum (LS): there is only one fixed amount to be corresponded for the overall contract. In certain cases, the Lump Sum price may be split into n-Lump Sum items;
- Reimbursable (or Cost plus fee): only documented costs are corresponded plus a fee which can be fixed or a percentage of the costs amount;
- Unit Prices: they are used mainly regarding Construction activities. Unit Prices are considered adequate if the Project quantities are subject to variations up to + or – 10%. If higher variations are registered or some activities are not priced, it is necessary to agree upon new prices.

Further detailed payments methods can be found in the Table 2.1.

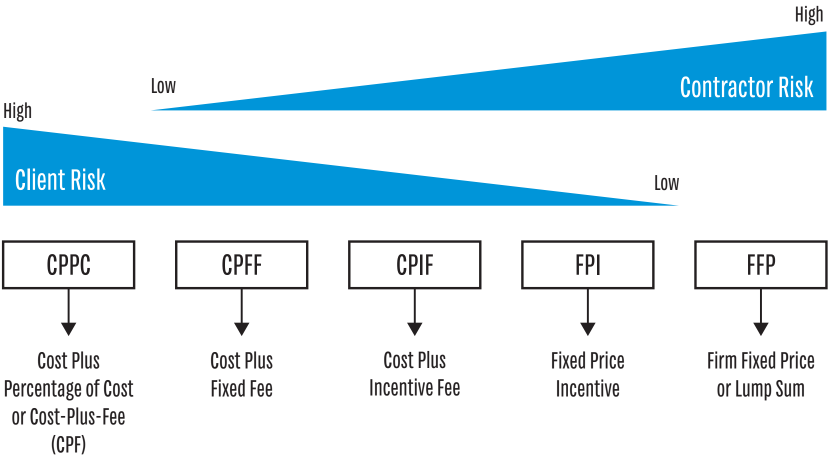
It is not possible to define a unique contract type valid for all types of Projects. All the various contractual formulas, in fact, bring different advantages and disadvantages to the parties involved and one of the emerging area of interest in other sector is the definition of continuously new types of contracts.

There are cases where a combination of different types of contract can occur in the same project. For example, Projects may start with reimbursable forms then converted into Lump Sum when the scope becomes clear enough.

Since a contract is the definition of the responsibilities of the involved parties, it is directly related to the risk shared among the stakeholders (as shown in Figure 2.5).

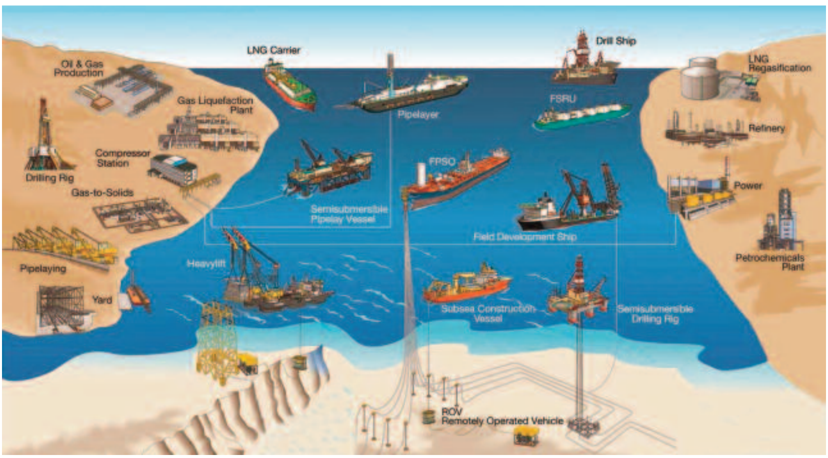
Type of Contract	
	Cost-plus perecentage fee
	Cost-plus fixed fee
	Cost-plus guaranteed maximum
	Cost-plus guaranteed maximun and shared savings
	Cost-plus incentive [award fee]
	Cost and cost sharing
	Fixed price or lump sum
	Fixed price with redetermination
	Fixed price with incentive/penality
	Fixed price with economic price adjustement
	Fixed price incentive with successive targets
	Fixed price for services, material and labor at cost [purchase order, blanket agreements]
	Time and material/labor hours only
	Combinations

[Table 2.1 – **Types of contract (Siirtec Nigi)**]



[Figure 2. 5 – **Main contracts types and associated risks (Siirtec Nigi)**]

2.6 Location and other factors characterizing a Project execution



[Figure 2. 6 – **Classification of Oil & Gas Projects (Saipem)**]

In the Oil & Gas field projects can be classified as Downstream/Upstream and Onshore/Offshore. Onshore projects can be further split into two sub-categories: “Brown Field” (also known as

"Brown Root") and "Green Field" (or "Grass Root") projects.

A "Brown Field" project consists in a Plant located in an Industrial Area where other facilities and services are already in place. Their presence constitutes a great help along the execution phase. Constraints can be here represented by the need to have several projects under Construction at the same time.

If no facilities are already up and running in the area, the project is referred to as "Green Field".

Almost every area from the metropolitan one to the harshest environments (like deserts, Artic/Antarctic, swamps, wild forests, mountains) can host a plant. Different project constraints must be then taken into account such as seismic conditions, extreme weather condition, seasonal conditions etc., and all of them requires specific construction techniques.

Usually onshore plants are built with a stick built approach. Here single elements are pre-fabricated and erected on site. Nowadays modularization, originally destined for Off Shore Projects only, is more often considered a valid alternative to the stick built approach for On Shore Projects as well. Different extents are possible, from full modularization to limited modularization and/or skid fabrication depending upon cost benefit evaluation, involved technologies, availability of local resources, availability of local infrastructures and severe weather conditions (see "Advances in plant modularisation", ANIMP).

In complex construction projects, especially in modularized ones, logistics play a very important role.

There are some contexts, like Revamping Projects of plant units, where prefabrication, modularization and skid solutions are commonly employed as well as multi-shifts operations, in order to mitigate the duration of the activities. In fact, a limited shutdown time of the plant means a lower production loss for the unit.

An overview to better understand the importance and the complexity of Revamping Project can be found in the article "Revamping of Control & Automation Systems" (Lorenzo Ferrè, 2013).

[Figure 2.7 – **Diesel Engine transport for Komsilga Project Burkina Faso (Fagioli)**]

2.7 Local Authorities and other local Organizations

Any foreign EPC Contractor has to establish contacts with national Authorities, especially for certification, and other Local Companies. This procedure is conducted with assistance coming from the Client Organization.

The EPC Contractor legal presence in a foreign country is ensured either by a Company Branch or by a locally registered company. In both cases the main operative benefit is the support that this entity may provide to the project execution in terms of: industrial relations, commercial contacts with clients, assistance in the immigration procedures, personnel health assistance, custom clearance, local insurances, logistic support for people, material and equipment transportation, local personnel recruitment, local material purchasing and subcontracts/services agreement, etc.

Often the Company Branch is located in the nearest town to the construction Site.

Other external bodies and Authorities to be considered are:

- Clerical Authorities;
- Police;
- Authorities in charge of Environment aspects (pollution, waste, etc.);
- Medical organizations and Hospitals;
- Labour Unions (mainly in UK, North America and Australia);
- Communities (mainly in Africa);
- Manpower Agencies;
- Utilities Suppliers;
- Harbour Master;

3 | Construction organization

The largest EPC Contractors usually entail in their organization a dedicated Construction department. It works in the Home Office defining guidelines and company practices for their worldwide construction activities. Construction department functions span from a project tendering phase up to the execution one, providing construction management in terms of: execution plan definition, direct hiring and/or subcontracting policy (selection of subcontractors and technical bid evaluation), temporary construction facilities, planning, direct/indirect man-hours estimate, organization chart, relevant cost estimate, construction procedures, works accounting, logistics, feedbacks gathering from all sites as for discipline productivity, typical costs, etc.

Middle and intermediate EPC Contractors and pure Construction Contractors may choose, instead, slimmer high efficiency organizations where construction organization overlaps with the overall project management/company functions.

3.1 The Project Organization Chart

Every EPC Contractor, as soon as it has to execute a Project, gives shape to an ad hoc Project Organization. In certain cases, this Organization can operate as a Task Force. A Task Force is a full time working group of people specifically gathered for the Project itself.

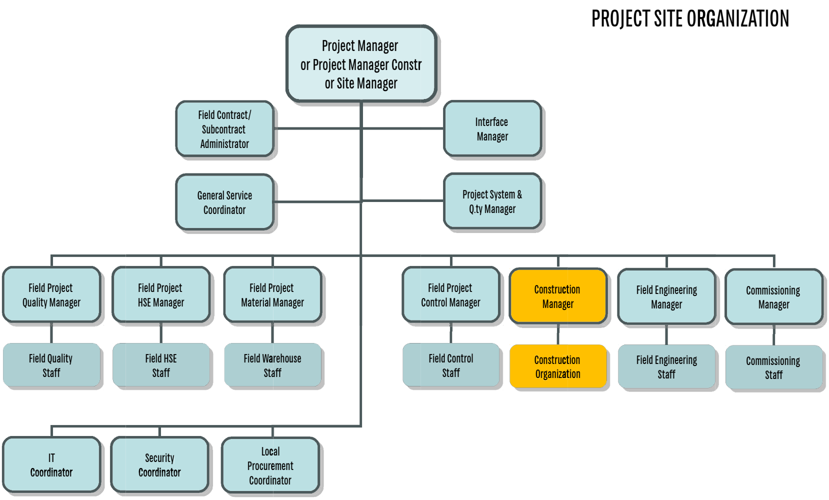
At the beginning, Clients usually place their Project Representative Team in the EPC Contractor Home Office only to move it on site later on.

The EPC Contractor Task Force complies with the same approach.

High flexibility is required to meet all the Project needs based on parameters like: division of responsibilities, product/technology, type of contract, Client requirements, size and complexity of the project, context/restrictions of the Country where the work has to be carried out, etc.

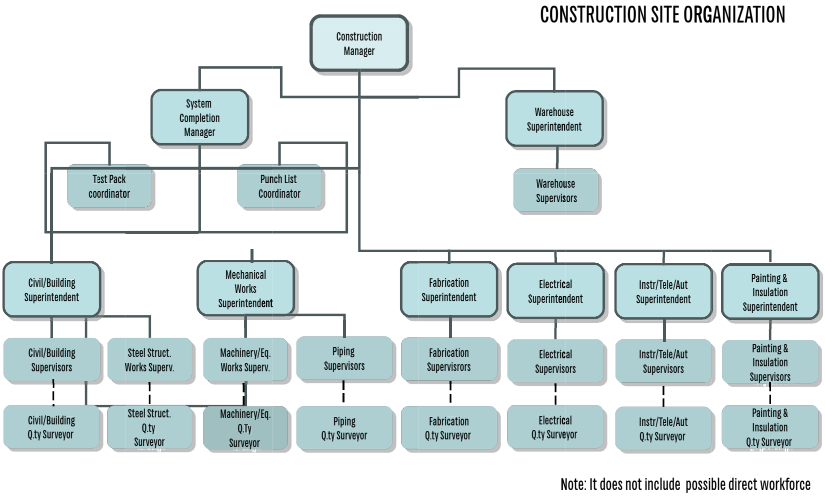
Along a project life-cycle, organization may slightly be modified, addressing the above parameters, until a satisfactory setup is achieved. While getting close to construction completion, such organization will naturally decrease in resources shrinking to its essential functions in the handover phase.

The site organization chart represented in Figure 3.1 constitute a general reference for an average EPC plant project. It shows the levels and the hierarchical dependences within a project among the most important functions required to execute the work at site. The chart is simplified for a quick understanding of the whole complex so, all lower level positions, are not specified.



[Figure 3.1 – **Example of simplified Organization Chart in EPC Projects**]

Figure 3.1 Bis further shows a possible detailed organization of the sole Construction component on site.



[Figure 3.1 Bis – **Example of simplified Construction Organization Chart for the site in EPC Projects]**

3.2 The Construction Organization Chart

The Construction Organization chart above refers to Construction activities only. But they can be split into two major phases and locations:

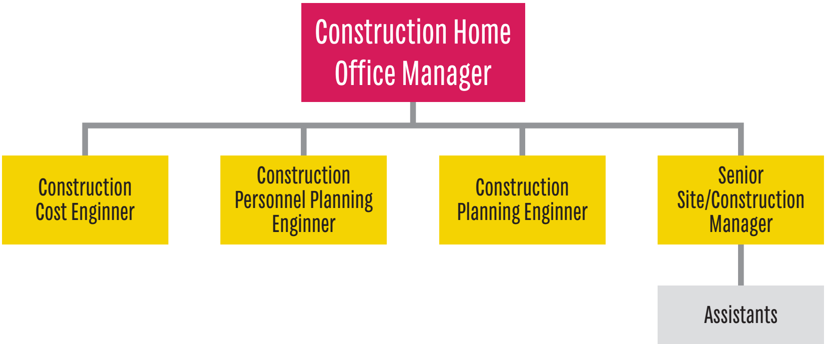
- Home office;
- Site.

In particular, Home office construction activities are focused on the identification of technical/economical/management solutions in terms of planning, subcontracting, constructability, feasibility, site organization and site opening requirements. Construction Home Office Manager responsibilities consist of Specialized Departments and a group of Senior Site/Construction Managers in charge of controlling the bidding phase and the execution one (see Figure 3.2).

Site construction activities, instead, relate to all Site activities, carried on through subcontractors or direct hiring management, and other local functions.

Site Construction Management first objective is the progress achievement in respect of Safety, Quality and cost which reverberates in good resources management and completion targets focus.

Project classified as of "High Complexity" may require a dedicated construction team inside the Task Force organization.



[Figure 3.2 – **Example of Home Office Project Construction Organization]**

4 | Construction activities project evaluation

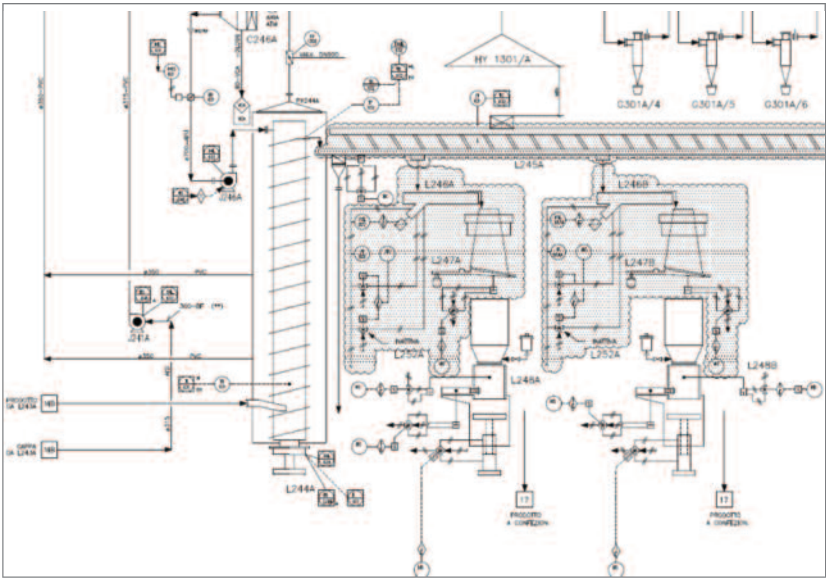
In an EPC Contractor organization, Construction Department shall receive from other Departments, like Process Engineering and Detailed Engineering or Procurement and Subcontracting, needed deliverables (drawings and documentation) to execute the Project.

Construction Department has also the responsibility to directly collect data and information from any other source (e.g. cost, logistics, local productivity, etc.), in order to properly plan and organize the Construction activities.

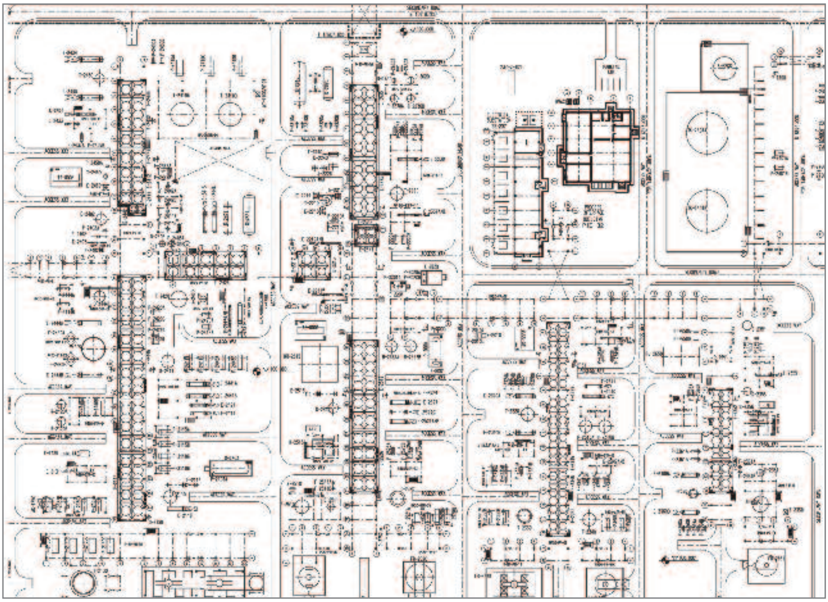
The big challenge is to manage this huge number of data and parameters. They are often generated for different targets and with different software solutions not always fully integrated between themselves. The article "Transforming Diverse 3D Data into Focused Information" (David Whittle, 2013) provides a possible solution to manage the interoperability problem.

4.1 Data from Process Engineering and Detailed Engineering

Process Department produces Equipment Process Data sheets and Piping and Instrumentation Diagrams (P&IDs). These documents show the equipment, piping and instrument connections, illustrating the Process logic (see Figure 4.1).



[Figure 4.1 – **Piping and Instrumentation Diagram (Saipem)**]

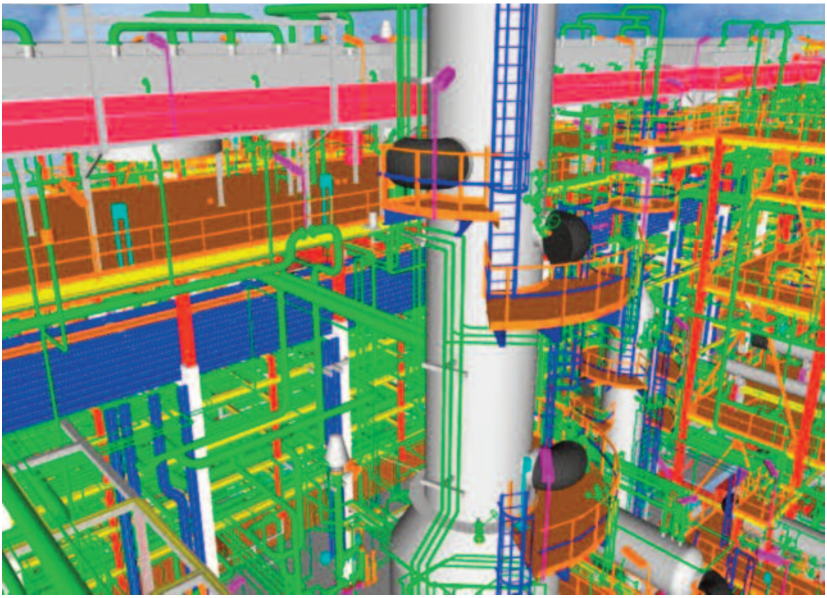


[Figure 4.2 – **Plot plan (Saipem)**]

	TAG ITEM			TYPE	DIMENSIONS			MATERIAL		OTHER INFO (DATA x UNIT)		
WBS	MAIN TAG/ITEM NUMBER	DESCRIPTION	TRAIN	TYPE	ID DIAM WIDTH (mm)	HEIGHT (mm)	LENGHT (mm)	I SHELL & CLAD SHELL CASING HEADER	II INTERNALS TUBE IMPELLERS	EXCHANG. TYPE AIRCOOLERS DRIVER TYPE HOWE	NR.SHELL NR BAYS	WEIGHT KG.
CLAUS	J30-D-1101	AMINE GAS KO DRUM	1	VESSEL	1400	3000		SA-516-70N + 3,2mm	316 SS	VE		4600
CLAUS	J30-D-1102	SWS GAS KO DRUM	1	VESSEL	1000	3550		SA-516-70N + 3,2mm	316 SS	VE		2660
CLAUS	J30-E-1104	AMINE GAS PREHEATER	1	HEAT EXCHANGER	1100		6096 tubes length	CS + 3,2 mm	SS+ 3,2 mm	BEU	1	13000
CLAUS	J30-D-1104	AMINE GAS PREHEATER CONDENSATE DRUM	1	VESSEL	750	2250		SA-516-70N + 1,6mm		VE		2615
CLAUS	J30-E-1105	SWS GAS PREHEATER	1	HEAT EXCHANGER	900		2438 tubes length	CS + 3,2 mm	SS + 1,6 mm	BEU	1	2500
CLAUS	J30-D-1106	SWS GAS PREHEATER CONDENSATE DRUM	1	VESSEL	750	2250		SA-516-70N + 1,6mm		VE		2615
CLAUS	J30-E-1107	CLAUS AIR PREHEATER	1	HEAT EXCHANGER	1500		4267 tubes length	CS + 3,2 mm	CS + 3,2 mm	BKU	1	26000
CLAUS	J30-D-1107	AIR PREHEATER CONDENSATE DRUM	1	VESSEL	750	2250		SA-516-70N + 1,6mm		VE		2615
CLAUS	J30-F-1101	CLAUS MAIN BURNER	1	FURNACE	2900		5580					25840
CLAUS	J30-F-1104-2	CLAUS MAIN BURNER CHAMBER	1	FURNACE	3700		10000					92800
CLAUS	J30-F-1103	CLAUS WASTE HEAT BOILER	1	FURNACE		7700	15500					126000
CLAUS	J30-D-1108	CLAUS WHB STEAM DRUM	1	VESSEL	2000		12200					26800
CLAUS	J30-E-1101	1ST SULFUR CONDENSER	1	HEAT EXCHANGER	2300		7320 tubes length	CS + 3,2mm CA	CS + 3,2mm CA	BEM	1	55000
CLAUS	J30-C-1101	1ST CLAUS CONVERTER	1	REACTOR	3900	~~14500~~	11500	SA-516-70N + 3,2mm		HO		31500
CLAUS	J30-D-1111	1ST REHEATER CONDENSATE DRUM	1	VESSEL	750	2250		SA-516-70N + 1,6mm		VE		2615
CLAUS	J30-E-1111	1ST CLAUS PREHEATER	1	HEAT EXCHANGER	1500		4267 tubes length	CS + 3,2 mm	SS + 3,2 mm	BKU	1	25000
CLAUS	J30-E-1102	2ND SULFUR CONDENSER	1	HEAT EXCHANGER	2300		7320 tubes length	CS + 3,2mm CA	CS + 3,2mm CA	BEM	1	55000
CLAUS	J30-C-1102	2ND CLAUS CONVERTER	1	REACTOR	3900	14500	11500	SA-516-70N + 3,2mm		HO		31500
CLAUS	J30-D-1112	2ND REHEATER CONDENSATE DRUM	1	VESSEL	750	2250		SA-516-70N + 1,6mm		VE		2615
CLAUS	J30-E-1112	2ND CLAUS REHEATER	1	HEAT EXCHANGER	1400		3958 tubes length	CS + 3,2 mm	SS + 3,2 mm	BKU	1	18500
CLAUS	J30-E-1103	3RD SULFUR CONDENSER	1	HEAT EXCHANGER	2300		7320 tubes length	CS + 3,2mm CA	CS + 3,2mm CA	BEM	1	55000

[Figure 4.3 – **Equipment list (Saipem)**]

Engineering Departments – Plant and Piping, Mechanical, Machinery, Civil, Electrical and Instrumentation – give an engineering definition of all components and connections. They produce drawings, specifications and detailed data sheets such as the plot plan – above and underground – (see Figure 4.2) and the equipment list (see Figure 4.3).



[Figure 4.4 – **3D Model (Saipem)**]

Engineering Departments also manage the 3D Model, where all the plant components are portrayed in place. Its adequate use allows to represent the majority of the plant details in order to avoid clashes and interferences (see Figure 4.4). Other opportunities offered by 3D Models are: plant operability, maintenance verification and progressive plant design review at various stages. To obtain information that is even more precise and better implement the design phase of a project with planning and construction activities, 4D models have been introduced. The use of this technology is portrayed, through a LNG case study description, in the article “Applicability of 4D modeling for resource allocation in mega liquefied natural gas plant construction” (Ying Zhou, Lieyun Ding, Xiangyu Wang, Martijn Truijens, Hanbin Luo, 2015).

Bill Item	Description	U.M.	Quantity	Labour Price	Material Price	Labour Price	Material Price
	CIVIL WORKS						
CIV 002	Limited section excavation for foundation works, basins or similar works up to 1.50 m depth using any suitable means, including the backfilling of voids left after the execution of the works:	M3					
CIV 004	Placing of fill for the general filling of plant areas in the presence of works already constructed, carried out with any appropriate means and even by hand if necessary, using material excavated, with minimal compaction degree:	M3					
CIV 007	Supply and placing in situ of concrete for reinforced casting, formwork to be ascertained and determined by making separated measurements / accounting, of whatever shape and size (e.i. walls, basins, columns, beams, slabs), for elevations over +1.00 m up to and including +7.00 m from plant finished floor level; for multi storey buildings, this item also applies to elevations over +7.00 m, including the installation of reinforcement bars:	M3					
	MECHANICAL WORKS						
MEC 001	ERECTION ONLY OF LARGE BORE PIPEWORK (welds & Joints accounted separately)						
MEC 002	ERECTION ONLY OF LARGE BORE PIPING "F" TYPE (INCLUDING FITTINGS AND FLANGES) FOR ANY THICKNESS						
MEC 004	FABRICATION AND ERECTION OF STEAM TRACING PIPEWORK AND STATIONS (WELDS INCLUDED)						
MEC 007	STEAM DISTRIBUTION/CONDESATE RECOVERY STATIONS FOR STEAM TRACING (SMALL BORE)						
MEC 008	COATING / WRAPPING APPLICATION ON PIPING INCLUDING REPAIRING OF ANY DAMAGED AREA AND COMPLETION WORKS						
MEC 013	PAINTING NON-INSULATED PIPES IN CARBON STEEL AND ALLOY STEEL - PREFABRICATED PIPES WITH OPERATING TEMPERATURE FROM 81 C. TO 200 C						
	ELECTRICAL WORKS						
ELE 001	INSTALLATION AND REASSEMBLY OF LV SWITCHGEARS						
ELE 002	Installation and reassembly of columns of power distribution LV switchgear, type power motor control center (PMCC) and auxiliary service panel (ASP)	NR	164				
ELE 003	INSTALLATION AND REASSEMBLY OF MV SWITCHGEARS						
ELE 004	Installation and reassembly of panels (e.g. incoming, bus-tie, user feeder, etc.) of air insulated (AIS) MV switchgears (over 1 kV up to 36 kV)	NR	46				
ELE 005	CABLE BUS						
ELE 006	INSTALLATION AND ASSEMBLY OF LV CABLE BUS						
ELE 007	Installation of LV cable bus, ampacity up to 2000 A, complete of cable supporting blocks, head ends, wall penetration accessories, covers, etc. and erection accessories	M	40				
	INSTRUMENTATION WORKS						
INSTR 001	INSTALLATION 01 OF FLOW AND LEVEL INSTRUMENTS Dp cell type. FLOW INSTRUMENT BARTON TYPE AND DIFFERENTIAL PRESSURE INSTRUMENT AND ACCESSORIES FIXED IN THE OPEN OR IN BOXES INCLUDING PRIMARY AND SECONDARY ASSEMBLIES (PNEUMATIC AND ELECTRICAL)WITH RELEVANT CONNECTION AND JOINTING TO THE INSTRUMENTS						
INSTR 005	INSTALLATION OF VALVE DIMENSIONS: SAFETY FROM 1/2" x 1" TO 1.5 x 2.5"; SELF-REGULATING UP TO 2"						
INSTR 012	CALIBRATION	NR	16				
INSTR 030	VALVE DIMENSIONS: SAFETY FROM 2x3" TO 4x6"; SELF-REGULATING FROM 3 UP TO 6"						
INSTR 032	CALIBRATION	NR	73				
INSTR 50	VALVE DIMENSIONS: SAFETY FROM 8x10" AND OVER; SELF-REGULATING FROM 10" AND OVER						

[Figure 4.5 – **Bill item (Saipem)**]

4.2 Data from Engineering and Procurement

Engineering Departments are also in charge of producing Material Take Off (MTOs) needed for the project bulk material procurement. Such MTOs, during the development of the detailed design, are released in many revisions with increased reliability. They so allow proper tuning of the procurement activities while the design progresses. At the same time, for each MTO revision, the Engineering Departments release corresponding Bill of Quantities (BoQs) for every relevant construction discipline. Quantities are detailed according to a predefined Work Breakdown Structure (WBS – for detailed definition see paragraph 6.4-) and finalized in an advanced phase of the project, when construction is already active on site. Usually, the last revision of BoQs constitutes of minor modifications compared to the previous ones, so that a precise planning and subsequent construction resources deployment may start in an early stage (manpower, construction equipment, indirect supervision).

As for the itemized materials (typical capital assets like columns, reactors, heaters, boilers, exchangers, pumps, compressors, turbines, etc.), the Procurement Department is able, as soon as it receives the relevant technical data sheets from the engineering departments, to explore the market about compliance with specifications, costs and delivery timeframes.

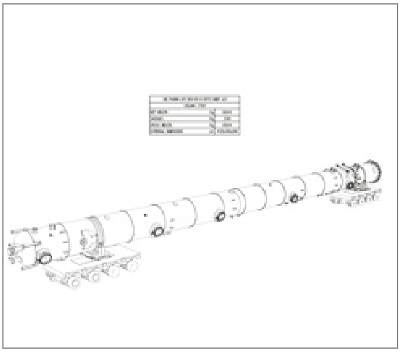
When Suppliers submit their offers to fabricate components, such as equipment or machineries, vendor technical data are evaluated by the Engineering Departments. In this phase data like (but not only) weights and dimensions, are checked and incorporated in the Project document as "Equipment List".

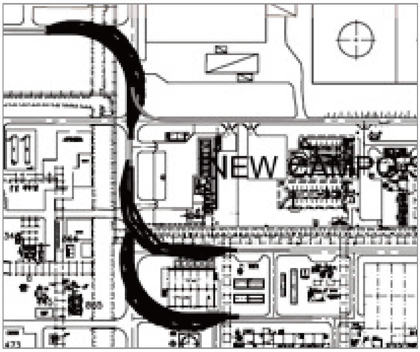
These kinds of information are necessary to produce Transportation and Lifting Basic Designs (see Figures 4.6 and 4.7). They contain information about the proper routing sequence and the lifting equipment required on site for their installation.

Once the Procurement Department selects the awarded Suppliers, Vendor drawings and specifications are delivered to the engineering departments in order to finalize the design and the 3D Model.

Complementary information from Suppliers such as installation, preservation and maintenance manuals are also needed by Construction specialists to evaluate if special activities are requested to handle equipment on Site.

Finally, procedures for the all project material handling are very important to properly manage Material warehousing.





[Figure 4.6 - **Transportation Design (Saipem)]**
[Figure 4.7 – **Accessibility Plan (Saipem)]**

4.3 Data from Site Surveys

Construction Department has to produce a Site Survey, visiting the Site and the surrounding areas (see Figures 4.8, 4.9, 4.10 and 4.11), in order to gather important information to carry out Construction activities.

[Figure 4.8 – **Site survey (Saipem)]**

Site Survey is usually assigned to a Senior Site Construction Manager, who can be assisted by a Civil Engineer and a Transportation Engineer. A Lifting Engineer can be brought in as well.

Starting from layout drawings produced by Plant, Piping and Civil Departments, all surrounding areas are deemed as space for Temporary Construction Facilities and their connection to the Plant area.

Site accessibility from/to different strategic infrastructures (e.g. roadways, harbors, railways, airport, others) shall be analyzed as well, being a key factor for the success of the project.

[Figure 4.9 – **Site Survey (Saipem)**]

[Figure 4.10 – **Site Survey (Fagioli)**]

Here below are listed the main subjects to be evaluated during a Site survey:

- General data of the project, site and surrounding;
- Availability of utilities like electrical power, water and communications, others;

- Soil Inspection;
- Climate;
- Geology;
- Transportation services (e.g. dumper, low beds, trailers, trucks, busses availability);
- Governmental regulations;
- Jobsite and customer's requirements;
- Purchasing and rental equipment;
- Local costs;
- Communications;
- Labour;
- Housing and food;
- Medical facilities;
- Emergency evacuation plan.

[Figure 4.11 – **Site Survey**]

5 | Construction activities evaluation

The Construction activities proper/better evaluation and control process, described later on, has been formalized, tested and revised through experience.

In a construction site, the only parameter that allows a comparison among the various performed activities is the amount of Man-hours these same activities require to be executed. It should be noted Man-hours calculation does rely on the unit of measure considered for a specific task (e.g. m3 – cubic meter of concrete to be casted rather that m – linear meter of cables to be pulled) or its peculiarity (e.g. concrete poured for a foundation compared with concrete poured for an elevated structure).

The following paragraphs will introduce further details to better explain the all process. This suggestion does not aim to be an absolute guideline but just an example of applied Construction activities evaluation to be used as possible reference.

5.1 Direct Productive Man-hours – DPMh

Usually, every project has its specific timeframe, that from the site opening to the plant mechanical completion (including the Pre-commissioning phase).

In big Construction Sites, different people are assigned to various activities. For example, there are individuals performing tasks concerning the erection of the Plant while others provide auxiliary services (Temporary Construction Facilities, warehousing, transporting people and materials from camps to Site, etc.). Finally, there are people taking care of Management and Supervision.

All Man-hours assignable to Site people can be first divided in two groups (see Figure 5.1):

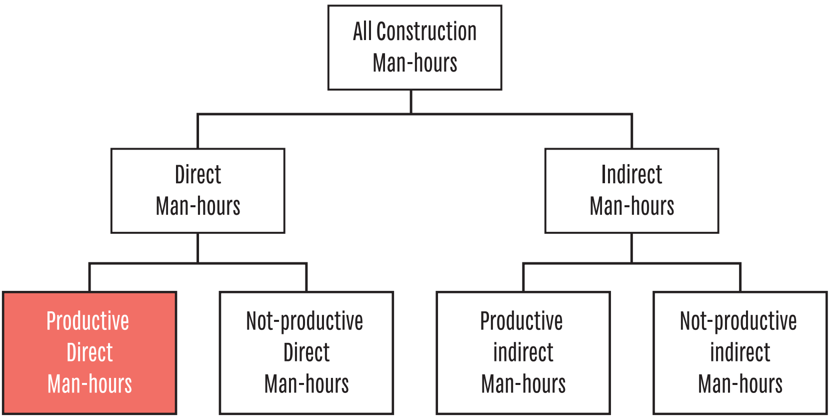
- Direct Man-hours;
- Indirect Man-hours.

Direct Man-hours refer to personnel directly contributing to the Construction progress, foremen (responsible to lead the various crews) included.

Indirect Man-hours are, instead, attributed to all personnel supporting the people actually performing the work.

A further division of both Direct Man-hours and Indirect Man-hours is between:

- Productive Man-hours;
- Non-productive Man-hours.



[Figure 5.1 – **Construction Man-hours classification]**

Productive Man-hours are those actually spent in production.

Unproductive Man-hours are those paid but not spent in production. They include annual vacation, public holidays, travel from/to place of residence, sickness and injury, paid or unpaid leave, industrial dispute, bad weather, lack of permits causing construction activities suspension, lack of essential utilities (electricity, water, air), lack of drawings and material, site emergency, force majeure, etc. Part of these hours (annual vacation, public holidays, travel, sickness and injury) may be already included in the hourly rate considered during the estimation phase (see also Paragraph 6.5).

Since the purpose of next paragraphs is to promote construction activities quantification methods, the attention will be focused on Direct Productive Man-hours only often considered as the main cost driver for the Construction phase.

5.2 Conversion from BoQ to Construction Standard Man-hours

Construction Standard Man-hours (SMh) are computed starting from Bill of Quantities (BoQs) by the introduction of Standard Productivity Rates (SPR). All the activities listed in the BoQs are transformed in SMh thanks the following expression (see Table 5.1 for example of BoQs conversion into SMh):

$$SMh = \frac{BoQ\ activities}{SPR}$$

SPR are based on collected data considered as average in different construction sites that can be so set as reference conditions. They refer to a productive theoretical area (i.e. Europe or Italy).

SPR are constant in time and they do not need revision exception made for specific technical improvement (for example technological improvements concerning the way specific activities are conducted, such as the introduction of concrete pumps in the concrete pouring).

5.3 Conversion of SMh in Direct Productive Man-hours

The Construction Standard Man-hours value represents a strong and stable reference. As such, they offer a first important tool to compare Projects conducted with similar approaches.

However, for any detailed construction activity estimation it is too generic. To partially cope with this aspect, it is necessary to refer to the so-called Direct Productive Man-hours (DPMh). SMh are

$$SMh \times K = DPMh$$

converted into DPMh thanks to the Productivity Factor (K):

Table n.	Explanatories Examples of calculation of SMh from Discipline BoQ				
Code	Construction Activity Description	Unit	BoQ	Standard Output	SMh
BC A3 110	Limited Excavation and Backfilling by machine up to - 1,5 m	cu.m	9.630	1,8	5.350
BC A4 110	Embankment for roads and yards, sub-base and base courses by machine	cu.m	4.590	3	1.530
BC C2 210	Casting of Reinforced Concrete for foundations, walls, structures underground up to + 1 m above ground inclusive of formwork and reinforcing steel	cu.m	2.790	0,15	18.600
BC F0 100	Erection of steel structures for Process Units and racks medium and heavy weight items with bolted connections	kg	275.040	36	7.640
CG E0 A10	Erection of packages skid mounted	kg	42.120	45	936
CP A1 01A	Prefabbrication in spools of large bore c.s. piping >=2" (Reference NPS 4") inclusive of branch connection	kg	153.125	12,5	12.250
CP A2 11A	Erection of large bore c.s. piping in spools and bars (reference NPS 4") on site	kg	159.790	9,5	16.820
CP A3 12A	Prefabbrication and erection of small bore c.s. piping < 2"	kg	18.750	2,5	7.500
CR F0 A10	Erection of assembled machines (pump + motor)	kg	24.375	25	975
CS D0 A10	Erection of Towers and Columns in one part	kg	36.900	90	410
CS G0 A31	Assembly and Erection of c.s. fixed roof tanks and accessories from prefabbricates plates	kg	178.464	26	6.864
DD B2 120	Installation of LV Main Switchgrears (Ref. Unit weight = 4,2 tons)	kg	10.300	20	515
DD C1 211	Layng of LV multicore cables with section <= 35 sq.mm u.g. buried or in cable ducts for power distribution	m	56.000	20	2.800
EE A1 100	Installation and calibration of pressure instruments with relevant accessories and supports (Ref. aver. support weight 5 kg each)	n	130	0,2	650
EE A2 100	Installation of Analyzers, Chromatographs, Sampling Syst.etc already inst. in assembled cabinets (Ref. Aver. Weight 500 kg)	n	6	0,04	150
FF A1 121	Insulation of hop piping NPS >= 2" (Ref. Thk. = 50 mm)	sq.m	864	0,6	1.440
FF B1 120	Isulation of cold piping NPS >= 2" (Ref. Thk. = 60 mm)	sq.m	246	0,3	820
GG A1 100	Sand blasting and priming by hands of c.s./a.s. prefabbricated piping spools with NPS between 2" - 6" (Ref. Sa 2,5 - priming thk. 75 micron)	sq.m	2.625	1,5	1.750
GG B3 300	Touch ups and finishing coats of machines and other moving equip.	sq.m	66	0,3	220

[Table 5.1 – **Conversion from BoQ to Construction Standard Man-hours**]

The Productivity Factor (K) is influenced by all the various factors that affect Productivity. The most important one is the Geographical Area where the work will be executed giving Productivity is commonly considered connected to Countries. For further details, see Paragraph 6.5.

Usually K has a value > 1, between 1.2 and 1.5 (average K can be set between 1.3 and 1.8 as well) reflecting the practical experience that the productivity is higher in industrialized countries respect to developing ones (in certain cases K can reach a value of 4).

Nevertheless, sometimes actual conditions can be even better than the standard one: that is K < 1 (like 0.9 or 0.8).

It should be noted that, by distinguishing SMh from DPMh, it has been introduced the distinction between the influence of the Plant design data, which affects only SMh (in charge of the Engineering Department) and the influence of Productivity which is conditioned only by K (in charge of Construction Department and Site Management). This division is of great support for the Construction Manager, who is always looking for elements to identify the reasons (sources and responsibilities) for discrepancies between planned and actual progress.

Productivity varies along the overall construction lifecycle but also in respect to different disciplines, site areas and Construction Sub-contractors.

The estimation of Productivity Factor based on a wide range of Projects assures its robustness and stability but particular project conditions force Construction Companies to estimate work hours considering specific Project characteristics.

Regarding DPMh and the Productivity Factor K (as well as factors K1 and K2 further mentioned in paragraphs 6.5 and 9.5), sometimes it's possible to find different definitions in the International Literature. For example, DMPh can be also referred to as Expected Man-hours (EMh).

Productivity Factor is often computed using the inverse formula, that is the ratio between SMh and DPMh. This means a K>1 now represents a Productivity higher than the standard one (better conditions if compared to the standard ones).

It becomes evident how important it is to properly define the terminology to be used before starting progress evaluation in order to obtain reliable results and lessons learned during and after the all project execution.

5.4 Construction Sub-contractor evaluation

When a Client or an EPC Contractor issues to Construction Sub-contractors a request for quotation, the Tender Package typically enquires for paramount importance information, including the DPMh estimated value. That is to evaluate whether the scope of works has been "well understood" in terms of complexity and related manpower requirement, compared to the internal estimate.

If the two values are comparable (5-10% of difference) both of them can be considered validated. If not, one of the two or both evaluations need to be revised. Both parties shall revise the assumptions up to the point when the values are reasonably comparable. In case of award, the common understanding on the manpower requirement may be used as baseline scenario to control the project.

Construction Contractor has also to break down the DPMh by craft to produce a proper trade workers quantification and a list of Construction Equipment and tools.

[Figure 5.2 – **Reactor lifting for Saipem GNL 3Z Project Algeria (Fagioli)**]

6 | Construction planning

Construction, as already said, is one of the most important phase of the overall Project. Therefore, a detailed planning must be carefully implemented. The Project Planner has to combine information concerning design, material availability and construction activities with Engineering and Procurement Departments in order to avoid conflict within systemic and detailed scheduling activities along the overall Project life cycle.

The Project Planner recognizes as well, a sound Project Plan shall be "Construction driven" or at least "Construction sensitive". Interdisciplinary meetings must be held during the Home Office phase to mitigate potential conflicts and/or out-of-sequence situations during Construction since all Construction requirements have to be absorbed within the Project Plan.

Good Construction Planning can be achieved through integration with Quality Management (QM) systems as described in the article "Integrating OHS, EMS and QM with constructability principles when construction planning – a design and construct project case study" (Y.J. Shen, D.H.T. Walker, 2001). After providing insights on integrated QM systems and discussing constructability principles, the article analyzes a case study project (the largest Australian freeway project) to show possible benefits coming from the adoption of this integrating approach.

As previously mentioned, the main basis for any Construction Planning is the total Construction activities DPMh value, with their direct relation to the duration of activities, phases and overall Plant Project.

In fact, thanks to the DPMh esteem an optimal duration of the Construction activities can be defined, on a case by case basis, that minimizes Construction costs, especially direct activities costs (e.g. manpower, equipment, scaffolding, etc.) and indirect activities costs (e.g. temporary construction facilities, areas/infrastructures rental, supervision, administrative organization, etc.).

The Construction manager has to perform as planned in order to achieve a construction cost level as close as possible to this minimum value.

If not, if the Construction time is strongly reduced (thanks to measures like unplanned accelerations, multiple shifts, intensive manpower density and consequent reduced productivity, increased and unplanned accommodation capacity, increased manpower transportation, etc.) as well as if it is increased (for example due to delayed engineering and/or procurement deliverables, low construction performance, bad weather conditions, strikes, stand-by caused by dispute with client, extension of running cost for temporary construction facilities, supervision, areas/infrastructures/equipment rental, etc.), resulting costs will be definitively higher.

Table 6.1 shows a possible relation between the total SMh and a specific type of project execution time. This relation SMh/Months cannot be considered in absolute terms but still represents an example of what the Construction Department of each Company has to develop internally for clusters of Plant Projects. There are other circumstances in Construction Planning that can reduce or increase Construction time, such as:

- Type of project;
- Site dimensions;
- Weather conditions;
- Construction Contractors knowledge and organisation;
- Specific intermediate milestone to be met.

SMh	Month(s)
50.000	6
100.000	8
250.000	11
500.000	14
1.000.000	18
2.500.000	24
5.000.000	30

[Table 6.1 – **Relation between SMh and time**]

6.1 Construction Planning Detailed Levels

A possible technique to determine the level of direct resources involved in Construction has been introduced through the evaluation of SMh and DPMh in Chapter 5.

Here the focus will be on the distribution rate of these resources during the Construction Period.

In a high level Construction Planning the time unit is the standard month (365 and 366 – for the leap years – days divided in 12 months, equal to 30.5 days). So being, the plan has not to be modified if the starting date changes, as time is independent from it (month 0, month 1,...,month N).

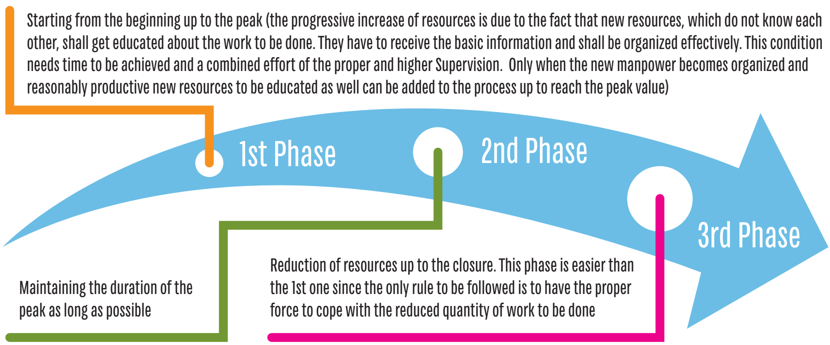
For further detailed Planning the appropriate time unit becomes the week. Calendar and individual vacation periods (Christmas, Ramadan, seasonal weather, national holidays etc.) have to be considered as well at this level.

Work hours peak value has to be limited as much as possible to obtain a cost-effective Construction activity, since many cost factors are number of direct workers dependent.

For a given timeframe, in fact, work hours peak value can highly impact costs same as the total Construction Activities duration (already pointed out as one of cost evaluation key factors).

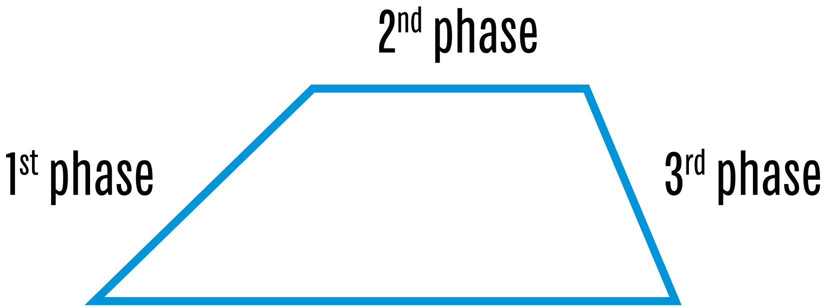
Most undeniable examples are the Construction Equipment and Personnel lodging Costs.

All considered, a proper resources rate distribution should be done as represented in Figure 6.1:



[Figure 6.1 – **Resources rate distribution**]

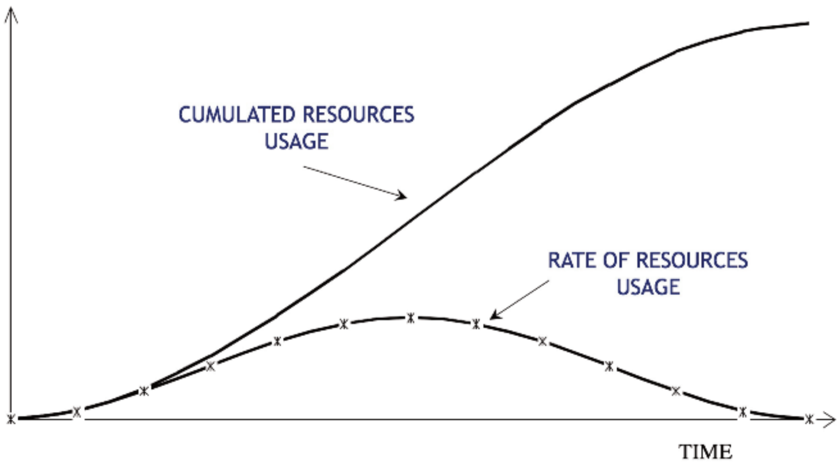
The optimal three-sequence resources rate distribution can be visualized in a trapezoidal shape curve (as illustrated in Figure 6.2). In this graph on the x-axis it is represented the time while on the y-axis the rate of resources involved (direct resources). The area underneath the curve then indicates the overall project effort.



[Figure 6.2 - **Optimal resources rate distribution curve**]

It should be noted that Productivity Factor K2 has been computed as the ratio between Actual Man-hours (AMh) and SMh (see paragraph 9.5). Based on what previously mentioned in paragraph 5.3, even K2 can be sometimes computed as the inverse ratio (that is the ratio between standard conditions and actual progress). In this case, the higher is the value the higher is the actual Productivity on site.

The curve also shows how the demobilization speed is, in average, faster than the mobilization one so the duration of the mobilization phase will be longer than the demobilization one (generally twice). The cumulative value of the resources rates distributions is known as S-curve distribution (see Figure 6.3).



[Figure 6.3 – **Example of cumulative resources distribution rate curve (also known as S-curve)**]

6.2 Construction Planning – Level 1 and 2

In Construction Planning, the first approach to be contemplates proportions between the three phases that can vary depending upon the size of the project. For example, in large/mega projects phase 2 may be longer in order to maximize the usage of resources and minimize the overall duration.

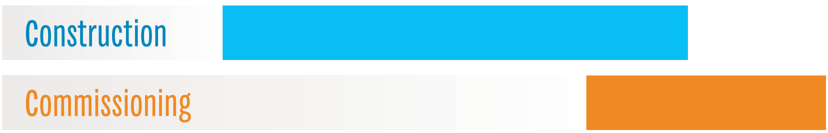
Usually, since a top-down approach is adopted, in general planning (previously represented and sometimes indicated as level 1), there is no distinction among the different parts of a plant. Moving on to a deeper level of detail (level 2) different boundaries are set, referring to process (or utilities) units.

Engineering data (BoQs), used to calculate SMh and DPMh, are therefore split accordingly to these different Units.

To distribute the resources based on Plant Units, several attempts are necessary. The resources rate distribution resulting shape should be sufficiently close to the level 1 one. As it happened, passing from level 1 to level 2, the new curve will be now considered next level main constrain.

A help to find proper resources rate distribution may come from PC software. In this case, though, a severe control from the Planning manager must be enforced; for example, only standard distribution curves, tuned following the originally suggested shape, can be adopted.

Mentioning Process Units means referring to the Commissioning phase. The passage from Construction to Commissioning is guided by the overlapping concept already explained in paragraph 2.3.



[Figure 6.4 - **Overlapping between Construction and Commissioning]**

This way of doing (see Figure 6.4) reduces the production time that brings to a shorter schedule. A shorter schedule is an indisputable advantage considering, for example, the loan interest in investment costs.

It becomes then clear how the Construction Plan should be "Commissioning sensitive" same as the Project Plan was "Construction sensitive". To enhance the overlapping of the two phases close coordination between Construction and Commissioning managers must be enforced.

Commissioning Function, as part of the Process Department, shall specify proper Process Systems Pre-Commissioning and Commissioning sequences. These sequences should provide for Units Construction completion dates in order to allow their final Commissioning.

Construction Planning shall implement the Pre-Commissioning and Commissioning sequences as defined by the Pre-commissioning, Commissioning and Start up Department. The only change allowed is the lag between the various plant units commissioning dates always paying close attention the final delivery date.

There are several types of Process Units accounted for different Oil and Gas Projects. To better explain the concept mentioned before a good example is provided by Utilities Units (Fire Water, Electric Power, Cooling Water, Instrument Air, Utility Water, Steam and Condensate, etc.), giving they are present in every Project. These utilities shall be "Ready for Commissioning" in the above-indicated order.

6.3 Construction Planning – Level 3

Improving details in Construction Planning requires distinction among disciplines.

A natural discipline sequence within the same Area/Plant Unit shall be then considered mandatory. An example of proper sequence for a specific area is:

- Piles;
- Foundations from the bottom-up;
- Underground works (piping first, cable after);
- Concrete paving;
- Above ground works (starting from steel structures);
- Equipment installation;
- Piping installation;
- Electrical/instrumentation works;
- Insulation and painting.

Planning of course shall be supported by relevant BoQ produced by the Engineering Departments.

As previously mentioned for levels 1 and 2, even level 3 resources rate distribution curve must follow an initial trapezoidal shape.

Each discipline shall have this trapezoidal shape, exception made for limited cases (e.g. pre-fabrication).

This type of planning is not easy and has to be done with several attempts choosing a proper work division and discipline sequence. At this stage the schedule will encompass all the drawings and materials availability for Site activities through the Engineering and Procurement Plans. At least one alternative schedule is recommended as result of a what-if analysis on potential critical equipment delivery delay.

6.4 Construction Planning – Level 4

At this stage, it is vital to foresee the work needed to complete a project. Work Breakdown Structure (WBS) offers a valid support to this problem. Discipline WBS can be even further decomposed in Work Breakdown Elements (WBE) to improve estimating, better control project execution and more accurately verify project completion. The use of historical information, that can add both speed and accuracy to future projects, is also guaranteed by this tool. Each company has its own glossary to define further level of division with a general agreement on the last one, commonly referred to as Work Package or Control Account (PMBOK 2014).

At this level of detail safety problems must be addressed as well, introducing the distinction among different site area. In fact, interferences among different trades can generate issues regarding Safety conditions and Productivity loss (for example in certain cases it is advisable to have only one trade working on a single area).

6.5 Estimated Productivity Factor – K1

All Construction Plans can be produced using SMh. There are no unexpected mistakes operating as such. It also makes easier to compare similar Plans.

However, there are several Construction aspects requiring reference to DPMh.

In order to cope with these needs it is necessary to resort on the Productivity Factor K, introduced in paragraph 5.3.

Further detailing, the one previously mentioned can be considered as the Estimated Productivity Factor (which from now on will be called K1).

It can be defined taking in consideration several different aspects as listed below. They have been brought up to the attention following observations on numerous Construction Sites (sometimes they are even mentioned in International literature).

They are:

- General economy of the country where the project has to be implemented;

- Typology and quality of the Industrial Relations in the Construction site country;
- Availability of manpower, Construction tools and Equipment;
- Climatic conditions of the country or the geographical area where the construction works have to be performed;
- Logistics efficiency providing raw materials;
- Unions presence in the area/country where the work is to be carried out;
- EPC Contractor Site Management and Supervision strength which can be measured by the professional level of the staff and also by the percentage of Construction Contractor Foremen, divided in experienced and neophytes ones compared to the labour force;
- Selection criteria of the Construction Contractors labour skills, resulting in a high qualitative level of direct and indirect personnel;
- Number of Construction Contractors permanent employees compared to the total amount of employees;
- Possible differences in the language in use between Supervision and Manpower;
- Average level of overtime work that is expected to be reached on Site by the Construction Contractor's personnel;
- Engineering sophisticated choices which can create obstacles in the execution of the works and/or difficulties in reaching the specified quality level;
- Labour density, which takes into account the expected concentration of direct personnel deployed in a given area or in the whole area of the plant to be constructed. These data are very important for personnel safety (see Paragraph 6.7).

The existing formulas to calculate the value of K1 based on the above factors are not easy to implement and the results cannot be guaranteed as acceptable.

It is then advisable to use the so-called Actual Productivity Factor (K2). This is the one effectively measured during the Project execution, considering previous works as reference (see paragraph 6.6).

The shape of the Plan curve should not change switching from K1 to K2. The value of the peak though may present important deviations.

The Actual Productivity Factor K2 (and the range) for each country is listed in Table 6.2.

PRODUCTIVITY FACTOR K2				
N	Country	Good	Average	Bad
1	Argentina	1,20	1,45	1,75
2	Australia	1,05	1,20	1,50
3	Brasil	1,30	2,25	2,85
4	Canada	1,05	1,15	1,40
5	China	2,00	2,30	3,00
6	Egypt	1,40	2,40	3,80
7	Europe	0,90	1,00	1,30
8	India	1,75	2,30	2,80
9	Japan	1,10	1,20	2,00
10	Kuwait	1,25	1,80	2,90
11	Malaysia	1,10	1,50	1,95
12	Nigeria	1,95	2,25	3,50
13	Russia	1,25	1,75	2,25
14	Saudi Arabia	1,30	2,20	3,30
15	United Kindom	1,10	1,20	1,60

[Table 6.2 - **Productivity factor K2 for different countries ("Global Construction Cost and Reference Yearbook", Compass International Consultants Inc., 2013)]**

6.6 The HSE impact in the planning

[Figure 6.5 – **HSE impact in the planning (Saipem)]**

Health, Safety and Environment (HSE) matters should be properly addressed while checking and finalizing a Construction Plan (see Figures 6.5 and 6.5 Bis). If needed, modifications should be advised.

Methods to address safety issues and implement proper solutions are described in the article "Construction design and management safety regulations in practice - progress on implementation" (Tony Baxendale, Owain Jones, 2000). The research presented in this article is based on structured interview with ten principal contractors and ten planning supervisors from small and medium size organization. Is then supported by a detailed case study condutcted in a Construction company.

The paragraph enlists examples of precautions useful to achieve high HSE quality in Construction. This subject will be later on recalled talking about Constructability (see Chapter 7).

Coordination among the various discipline crews, for example, as well as the use of visible signals and protections during excavations are two very important factors.

Lifting cranes and material handling operation in the construction area, which includes the area surrounding the units as well, shall be carefully planned.

The same goes for Plant ladders, stairs, platforms and scaffoldings erection, operation and dismantling.

If work has to be done at night, a temporary lighting system shall be provided assuring a sufficient level of visibility in all the areas where there are people at work including lay-down areas and roads.

Keep the areas clean is a prerequisite for Safety. At the end of the day and even after the conclusion of any operation, all scraps and debris shall be removed.

Expert Safety Supervisors are accountable for all operations and they should stimulate the support of all people located in working and transportation areas. The adoption of near miss and observation card reporting may give a huge support too.

[Figure 6.5 Bis – HSE meeting]

6.7 Labour Density

"Labor Density" was already mentioned in paragraphs 6.5 and 6.6, in relation to Productivity and HSE.

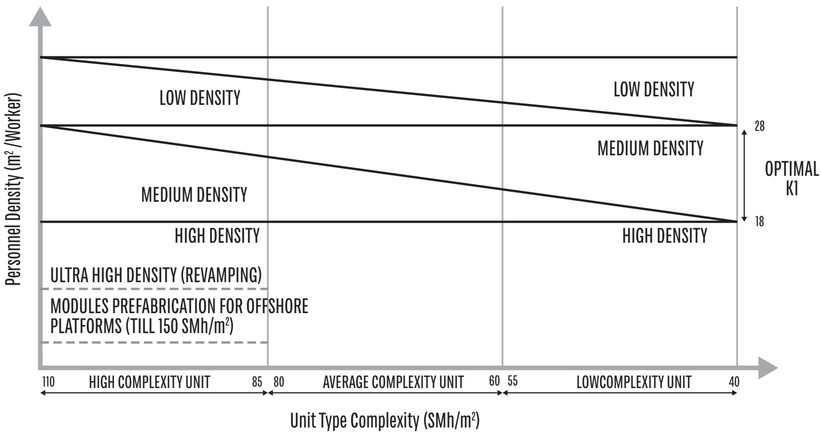
It is here presented a methodology to actually quantify it:

$$Labour\ Density = \frac{sqm}{n^{\circ}\ of\ workers}$$

Where:

$$n^{\circ}\ of\ workers = \frac{SMh \times K1}{working\ days \times 8\ hours\ shift}$$

The limit value for non-affecting productivity, coming from site experience, can be set between 18 and 28 m2/n° of workers as mentioned in the guide "Change and the Loss of Productivity in Construction: A Field Guide" (Dr. William Ibbs, Caroline Vaughan, 2012) (see Figure 6.6).



[Figure 6.6 - **Labour density diagram]**

Complexity, represented by SMh per m2, is considered acceptable if it is in the 60 to 80 SMh/m2 range.

Outside this range, if Complexity is lower than 60 SMh/m2 no problem is recorded while if it is higher than 80 SMh/m^2 the situation becomes critical.

In critical phases, usually associated with revamping work, it is not possible to change the work content in the area. The only way is to increase the Man-hour work per person per day. In extreme cases, it is even necessary to introduce double shifts.

Even if it is true that increasing in work hours or working in shifts can negatively affect single worker Productivity, the overall Productivity will actually increase. If, instead, no actions are taken regarding work hours or shifts, overall Productivity will diminish and safety will be at risk. These options are to be then considered best among bad solutions.

Another example of high-density working situation is a module erection in the dedicated yard. In this case the area to be considered is much greater than the single module extension. In fact, all the surrounding areas, used by the construction team, have to be contemplated as well so extending the working one up to 6-10 times the module size.

6.8 Useful and useless planning

Planning can be achieved with the support of common computer based software such as Microsoft Project, Primavera, Company in-house and other commercial software solutions. Sometimes the use of these tools can lead to an exaggerated activities fractioning. That increases the amount of data to deal with and the related controlling cost.

In case of the activities number exceeds the threshold of 200/300 items, obtaining information becomes very hard and the validation of the plan is jeopardized.

Validation process is based on an iterative procedure that has to be put in place every 2-3 months due to the continuous variability of data and project performances. That guarantees a higher control of the schedule.

The definition of the best level of detail that combines good precision with reasonable data control is one of the biggest challenges in Construction Planning.

Experience suggests that, for an EPC Contractor, a good Construction Plan should not go down further than Level 3. Higher level of detail (level 4) can be used for specific or critical items installation only.

Level 4 is indeed requested by Construction Contractor in order to better control performances and carefully measure progress as well as the Actual Productivity Factor (K2).

For example, concrete can be subdivided in scaffolding, steel bars preparation, pouring and curing when partial SMh value has to be considered for incomplete works.

Talking about levels of detail, as already said each company has its own specific definitions. To help understanding the overall concept, examples of Construction Physical Progress Evaluation are presented in Figures 6.7 and 6.8.

DWG	SYSTEM	KG	RELATIVE WEIGHT	SandBl./Sect.	Assembly, tack welding	Welding	X-ray examination	Stress relieving	Transport to erection area	PROGRESS % ON ISO	PROGRES % ON PREFABBR.	EARNED KG
				WORK STEPS PIPING PREFABBRICATION								
				15,00%	20,00%	40,00%	10,00%	10,00%	5,00%			
				65,33%	45,16%	44,39%	38,92%	42,43%	26,50%			
200 - AD-800002 - 0 - Sh. 01	AD	6,50	0,00%	100,00%	100,00%	100,00%	0,00%	0,00%		75,00%	0,00%	5
200 - AD-800079 - 0 - Sh. 01	AD	109,64	0,04%	100,00%	100,00%	100,00%	0,00%	0,00%		75,00%	0,03%	82
700 - AD-800025 - 0 - Sh. 01	AD	130,76	0,04%	100,00%	80,00%	80,00%	0,00%	0,00%		63,00%	0,03%	82
700 - AD-800025 - 0 - Sh. 02	AD	556,84	0,18%	100,00%	60,00%	60,00%	0,00%	0,00%		51,00%	0,09%	284
700 - AD-800025 - 0 - Sh. 03	AD	73,00	0,02%	100,00%	95,00%	95,00%	0,00%	0,00%		72,00%	0,02%	53
700 - AD-800036 - 0 - Sh. 01	AD	408,23	0,13%	100,00%						15,00%	0,02%	61
700 - AD-800037 - 0 - Sh. 01	AD	32,06	0,01%							0,00%	0,00%	0
700 - AD-800038 - 0 - Sh. 01	AD	11,55	0,00%	100,00%	100,00%	100,00%	0,00%	0,00%		75,00%	0,00%	9
700 - AD-800044 - 0 - Sh. 01	AD	124,50	0,04%	100,00%	100,00%	100,00%	0,00%	0,00%		75,00%	0,03%	93
700 - AD-800046 - 0 - Sh. 01	AD	28,92	0,01%	100,00%	100,00%	100,00%	100,00%	0,00%		85,00%	0,01%	25
700 - AD-800049 - 0 - Sh. 01	AD	10,09	0,00%	100,00%	100,00%	100,00%	0,00%	0,00%		75,00%	0,00%	8
700 - AD-800050 - 0 - Sh. 01	AD	22,26	0,01%	100,00%	100,00%	100,00%	0,00%	0,00%		75,00%	0,01%	17
700 - AD-800052 - 0 - Sh. 01	AD	29,29	0,01%	100,00%	100,00%	100,00%	50,00%	0,00%		80,00%	0,01%	23
700 - AD-800059 - 0 - Sh. 01	AD	40,85	0,01%							0,00%	0,00%	0
700 - AD-800061 - 0 - Sh. 01	AD	6,65	0,00%	100,00%	100,00%	100,00%	0,00%	0,00%		75,00%	0,00%	5
700 - AD-800063 - 0 - Sh. 01	AD	95,01	0,03%	100,00%	100,00%	100,00%	0,00%	0,00%		75,00%	0,02%	71
700 - AD-800064 - 0 - Sh. 01	AD	1,65	0,00%							0,00%	0,00%	0
700 - AD-800068 - 0 - Sh. 01	AD	68,80	0,02%							0,00%	0,00%	0
700 - AD-800073 - 0 - Sh. 01	AD	24,27	0,01%	100,00%	100,00%	100,00%	0,00%	0,00%		75,00%	0,01%	18
700 - AD-800075 - 0 - Sh. 01	AD	60,96	0,02%	100,00%						15,00%	0,00%	9
700 - AD-800078 - 0 - Sh. 01	AD	6,52	0,00%	100,00%	100,00%	100,00%	0,00%	0,00%		75,00%	0,00%	5
700 - AD-800082 - 0 - Sh. 01	AD	35,47	0,01%	100,00%	100,00%	100,00%	0,00%	0,00%		75,00%	0,01%	27
800 - AD-800011 - 0 - Sh. 01	AD	50,15	0,02%							0,00%	0,00%	0
800 - AD-800011 - 0 - Sh. 02	AD	15,54	0,01%							0,00%	0,00%	0
800 - AD-800012 - 0 - Sh. 01	AD	72,11	0,02%							0,00%	0,00%	0

[Figure 6.7 – **Detailed Planning (Siirtec Nigi)**]

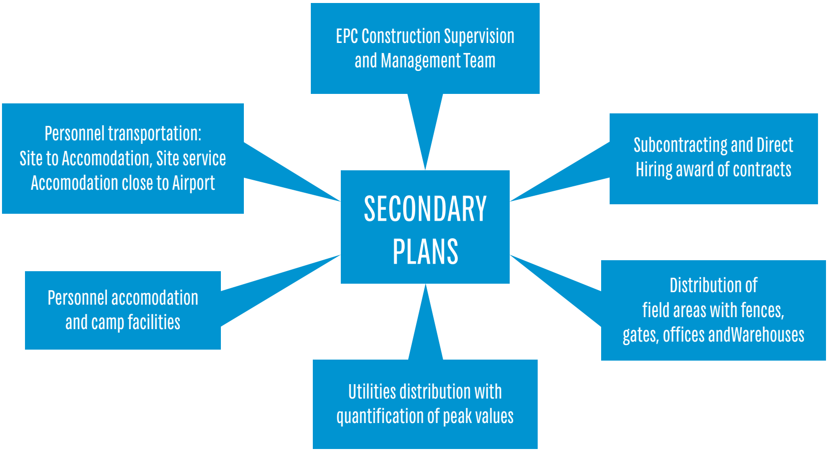
Equipment Erection

EQ.TYPE	Equipment TAG N.	Equipment Description	WEIGHT (KG)	Grid	Support	Elevation	Relative Weight %	MAT. AL SITE	ERECTION	Levelling / Plumb adjustment	Internal Ass.	Aux.Struct.	Final Allign.	Grouting	Final Inspect.	Final Erect. & Accept. QC doc.	PROGRESS % ON EQUIPMENT	PROGRESS % ON ACTIVITY
								EQUIPMENT ERECTION										
								5,00%	45,00%	10,00%	15,00%	10,00%	5,00%	2,00%	3,00%	5,00%		
								92,23%	82,55%	79,50%	65,89%	7,53%	48,78%	0,00%	0,00%	0,00%		
Static	E-101 (**)	Thermal Reactor, WHB, Steam Drum	**60.000,0**	Grid 20-27 (A1)	Fnd	2.800,00	9,04%	100,00%	100,00%	100,00%	100,00%						75,00%	6,78%
Static	V-108 (**)	Thermal Reactor, WHB, Steam Drum	**7.500,0**	Grid 20-27 (A1)	Fnd	6.460,00	1,13%	100,00%	100,00%	100,00%	100,00%						75,00%	0,85%
Static	H-101 (**)	Thermal Reactor, WHB, Steam Drum	**70.000,0**	Grid 20-27 (A1)	Fnd	4.100,00	10,54%	100,00%	100,00%	100,00%	100,00%						75,00%	7,91%
Static	H-301 (**)	Incinerator	**16.000,0**	Grid 01-08 (A3)	Fnd	2.400,00	2,41%	100,00%	100,00%	100,00%	100,00%		100,00%				80,00%	1,93%
Static	B-101	Burners	**1.500,0**	Grid 20-27 (A1)	Fnd	4.100,00	0,23%	100,00%									5,00%	0,01%
Static	B-301	Burners	**1.800,0**	Grid 01-08 (A3)	Fnd	2.400,00	0,27%	100,00%									5,00%	0,01%
Auxiliary	X-501	Injection Package	**1.500,0**	Grid 09-20 (A2)	Fnd	0,00	0,23%	100,00%									5,00%	0,01%
Auxiliary	X-602	Injection Package	**1.700,0**	Grid 20-27 (A1)	Fnd	0,00	0,26%	100,00%									5,00%	0,01%
Auxiliary	X-801	Injection Package	**1.500,0**	Grid 20-27 (A1)	Fnd	0,00	0,23%	100,00%									5,00%	0,01%
Rotating	P-202 A/B	Sealless Pumps	**530,0**	Grid 09-20 (A2)	Fnd	0,00	0,08%	100,00%			100,00%						20,00%	0,02%
Rotating	P-203 A/B	Sealless Pumps	**600,0**	Grid 09-20 (A2)	Fnd	0,00	0,09%	100,00%			100,00%						20,00%	0,02%
Rotating	P-501 A/B	Sealless Pumps	**262,0**	Grid 01-08 (A3)	Fnd	0,00	0,04%	100,00%			100,00%						20,00%	0,01%
Rotating	P-502 A/B	Sealless Pumps	**262,0**	Grid 01-08 (A3)	Fnd	0,00	0,04%	100,00%			100,00%						20,00%	0,01%
Rotating	P-603 A/B	Sealless Pumps	**200,0**	Grid 20-27 (A1)	Fnd	0,00	0,03%	100,00%			100,00%						20,00%	0,01%
Rotating	P-801 A/B	Sealless Pumps	**710,0**	Grid 20-27 (A1)	Fnd	0,00	0,11%	100,00%			100,00%						20,00%	0,02%
Rotating	P-802 A/B	Sealless Pumps	**1.100,0**	Grid 20-27 (A1)	Fnd	0,00	0,17%	100,00%			100,00%						20,00%	0,03%
Rotating	P-803 A/B	Sealless Pumps	**240,0**	Grid 09-20 (A2)	Fnd	0,00	0,04%	100,00%			100,00%						20,00%	0,01%
Rotating	P-804 A/B	Sealless Pumps	**292,0**	Grid 20-27 (A1)	Fnd	0,00	0,04%	100,00%			100,00%						20,00%	0,01%
Rotating	P-401A/B	Sulphur Delivery Pumps P-401 A/B	**2.200,0**	Grid 09-20 (A2)	Fnd	0,00	0,33%	100,00%			100,00%						20,00%	0,07%
Rotating	P-601 A/B	Boiler Feed Pumps	**5.000,0**	Grid 20-27 (A1)	Fnd	0,00	0,75%				100,00%						15,00%	0,11%
Rotating	P-602 A/B	Boiler Feed Pumps	**2.600,0**	Grid 20-27 (A1)	Fnd	0,00	0,39%				100,00%						15,00%	0,06%
Auxiliary	J-401 A/B/C	Steam Ejector J-401 A/B/C	**1.500,0**	Grid 09-20 (A2)	Fnd		0,23%										0,00%	0,00%

[Figure 6.8 – **Detailed Planning (Siirtec Nigi)**]

6.9 Secondary Plans

Examples of Secondary Plans are (see Figure 6.9):



[Figure 6.9 - **Secondary Plans]**

EPC Contractors have to implement several Secondary Plans (supervision and management, logistics, facilities, etc.) to coordinate each project site.

Secondary Plans are established by Construction Contractors as well, in compliance with their scope of work and EPC Contractor general assumptions.

Focusing on supervision and management, the plan is based on the development of the organization chart and the various qualifications bar chart.

So being, it is much better to refer to SMh, instead of DPMh, since these activities have minor connection to productivity.

The Supervision and Management Plan is produced using a bar chart indicating:

- Positions;
- Country of origin;
- Mobilization and Demobilization Dates;
- Total man-months (they can be transformed in man-hours in order to check the proper total SMh ratio).

Acceptable values of supervision and management ratio are usually lower than 12%. Higher project dimension suggests even lower value of this percentage (till 8%).

6.10 Planning periodic updating

Provided that, the mission of the project team is to keep the Construction Plan untouched, any eventual change has to be considered an extraordinary event.

Main reasons for changes are usually:

- Soil and geotechnical problems;
- Engineering changes and mistakes in the Project;
- Critical materials and equipment delivery delays;
- Heavy changes in BoQs (piping, support, etc.);
- Trade Unions
- Construction delays due to some Construction Sub-contractors' poor performance.

Every time a change is made according to these reasons, it must be analysed and approved by the Client and the main Stakeholders from the Contract point of view.

Under this assumption, any ordinary monthly planning update should be done based on the original construction plan.

Until this plan is in place, input data changes, progress and delays are registered but not included in it.

Operating in this way gives a more perceivable indication of the construction status. It even helps stimulating reactions in the Management team.

If the Management Team does not have an adequate level of maturity, there is the risk of continuous modifications in the Construction plan that can be seen as possible delay justifications.

When it becomes clear, comparing Progress with the existing Plan, a new way is required to stay on target and a recovery Plan shall be implemented.

If that is the case, all Engineering and Procurement new data have to be included in this Plan (same for the updated K1 value).

To further help this Construction Planning phase, a list of guidelines is presented below:

- Civil works can start when enough drawings are available on site, usually from 4 to 6 months after the EPC contract award;

- Piping underground (u/g) installation can start at 20% of civil activities. The optimum approach is to carry-out u/g activities by area in order to complete the paving on time and avoid disruption to other discipline activities above ground (a/g);
- Piping fabrication can start approximately at 40% of civil activities (usually 10 to 12 months from the beginning);
- Piping erection can start approximately at 50-55% of civil activities;
- Piping erection can start at 60% of pipe-rack erection;
- Insulation can start when hydrotest are 50% in weight;
- Hydraulic tests (for specific area of the plant) can start at 40% of piping erection. Gap between the Hydraulic tests phase and the piping erection one decrease at 20% when piping erection reaches 70%;
- Painting can start with the piping prefabrication. It can even begin before that, with piping bars primerization (especially for small bore pipes and for pipes to be installed on pipe rack);
- Electrical installations can start when substations civil activities reach 90%, the pipe-rack is fully installed and the mechanical activities are at 40%;
- Instrumentation works can start when control room civil activities reach 90%, the pipe-rack is fully installed and the mechanical activities are at 50%;
- Insulation works can start when mechanical works reach 60%;
- Pre-commissioning can start when mechanical works reach 85%.

Results cannot be assured in a mathematical way and even with honest attempts, conflicts remain among Engineering, Procurement and Construction Departments.

Usually disputes are managed thanks to the Project Manager authority and sensibility.

7 | Constructability

7.1 What is Constructability - Definition

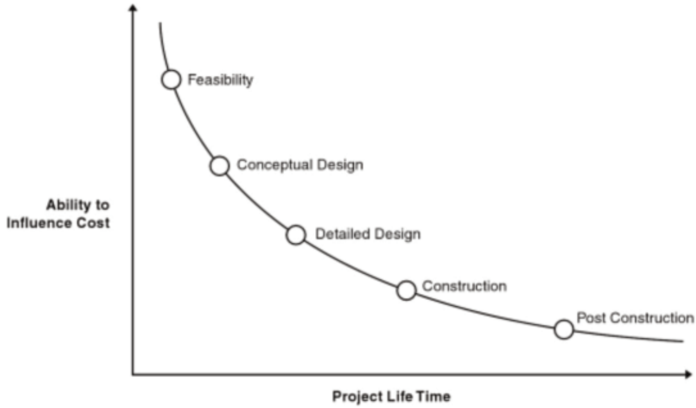
Through the years, Constructability has been defined in several ways as shown in the articles "Development of constructability concepts, principles and practices" (A. Griffith, A.C. Sidwell, 1997) and "A study of measures to improve constructability" (Franky W.H. Wong, Patrick T.I. Lam, Edwin H.W. Chan, L.Y. Shen, 2007). Nevertheless, the most commonly quoted definition is The Construction Industry Institute (CII) one, which goes back to 1986. The CII defines Constructability (1986) as:

"the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives. Maximum benefits occur when people with construction knowledge and experience become involved at the very beginning of a project."

Constructability is the mean by which Clients, EPC and Construction Contractors and Consultants bring into a new project benefits coming from feed-backs and experiences on Construction, collected among their designers, planning specialists, procurement engineers, construction and commissioning professionals.

7.2 Effects of Constructability in project life cycle

Decisions ability to influence final cost over project life is portrayed in the following graph (see Figure 7.1):



[Figure 7.1 – **Ability of decisions to influence final cost over project life]**

As the curve demonstrates, Constructability is highly successful in the early phase of the project, when Conceptual Planning has to be performed. Constructability can bring positive effects later on as well, but with lower impact in terms of project performances.

In order to achieve maximum effectiveness, Design Engineers, even if they have some experience in Construction, shall not be left alone while producing plot plans and plant configurations. They have indeed to involve Senior Construction expertise (e.g. Construction and Site managers) to foresee possible Construction strategy future developments and/or alternative solutions.

Senior Construction Engineers can in fact prompt ideas with big impacts on Construction development in terms of time and costs reduction.

For example, decisions directly related to the site location, if addressed too late, can even produce time loss and/or expensive changes in contractual clauses. Samples of previously mentioned decisions are:

- Module and preassembly improvement (skid mounted);
- Extent of standardization and prefabrication;
- Absolute priority of underground work in process units in order to have paving executed prior starting of hydraulic test;
- Pre-dressing of vertical columns before lifting.

The importance of implementing Constructability in Construction is also disclosed in the article "Constructability Methods and Tools" (Franco Concari, 2011).

7.3 Constructability Plan

At the beginning of the FEED and when a Project is ready for execution, a Project Constructability Plan shall be issued and it has to contain the following elements.

- A constructability procedure defining, in particular:
  - How many workshops to execute during the project and when;
  - The basic Construction approach that is stick built versus preassembly or modularization (even of small part of the plant) mainly if overall project schedule is construction driven;
  - Constructability program targets (improved definition of the plot plan, the Construction execution plan and the logistic plan);
  - Baseline scenario preparation (input documents for the baseline scenario preparation;
  - Lessons learned and similar projects constructability report, EPC Check List);
  - Deliverables to be produced and relevant owner;
- Organization (attendees, key figures roles and responsibility, Project Director, Constructability workshop leader, Constructability coordinator);
- Constructability topics and relevant champions (Discipline leaders);
- Monthly Reports to be produced.

The scope is to define all constructability aspects to be assessed (see also Table 7.1). First of all, proper contractual terms shall be understood and agreed upon. The key to success is then to be found in fully integration between all the people and the departments involved in the project (for example Senior Construction Managers and Engineers should work side by side).

Constructability also seeks to:

- Harmonize and integrate Engineering, Procurement and Construction;
- Assure the Maintainability and Operability of the Project;
- Perform site activities in respect of HSE with a Zero Accident target;
- Manage Quality Control Plan;
- Implement proven methods and techniques;
- Define efficient Construction Strategy;

» Monitor work physical progress;

» Maximize and plan pre-assembly and fabrication on ground;

» Reduce the amount of Direct Site Works using local suppliers for fabrication, pre-assembly and concrete pre-casting;

» Reach Planning optimization.

Lessons learned, coming not only from the EPC Contractors but also from all the parties involved in the project (Clients, Construction Contractors, Manufacturers, Suppliers), timely concise reports (for example Constructability Periodic Report) and updated records are of great help too.

When the time comes, Constructability should transfer from the Home Office to the Site to better ensure control over the Project. Finally, conclusion must be drawn and collected in a 'Final Constructability Report' to:

» Analyse how Constructability Concepts and Topics have been implemented and results achieved using records of Direct and Indirect Man-hours spent, Progress, Efficiency, Cost and Savings;

» List of lesson learned to be recorded in the Client and EPC Contract data for future reference.

	Basic and Front End Design	Detail Engineering and Construction (H. Office and Site)
Inputs	Plot plans Equipment list Lesson learnt Preliminary logistic study Preliminary procurement plan Survey reports Industrial relations Constructability check list	Plot plans U/G plot plan U/G cable routing Foundation drawings and plot plan Pipe-rack drawings and plot plan Piping arrangement Main equipment drawing Preliminary heavy lift equipment list Equipment list/MTO's Building list Topographic and geotechnical survey report 3D model Project schedule Procurement plan Heavy lift studies report Potential local constrain Logistic study report Traffic plan Permitting requirements/local constraints Constructability check list Handover to commissioning
Activities	Responsibility definition Road map (selected topics to lead brainstorming) Plot plans analysis and optimization Analysis of local key factors Market survey Preliminary man-hours estimation Preliminary construction camp, laydown area and temporary facilities sizing Preliminary accessibility analysis Preliminary modularization and pre-assembly analysis Specific constructability studies 1st issue of constructability action log	Plot plans and analysis and optimization Analysis of U/G plot plans and heavy lifts Construction sequence analysis Modularization and pre-assembly analysis Labour density analysis Accessibility review Construction equipment (carriage, trailers) Requirements and optimization Utilities, consumable and fluids (Nitrogen, power, water for hydro tests) requirements Construction camp, temporary construction Facilities and laydown area sizing Traffic plan analysis Schedule review Specific constructability studies

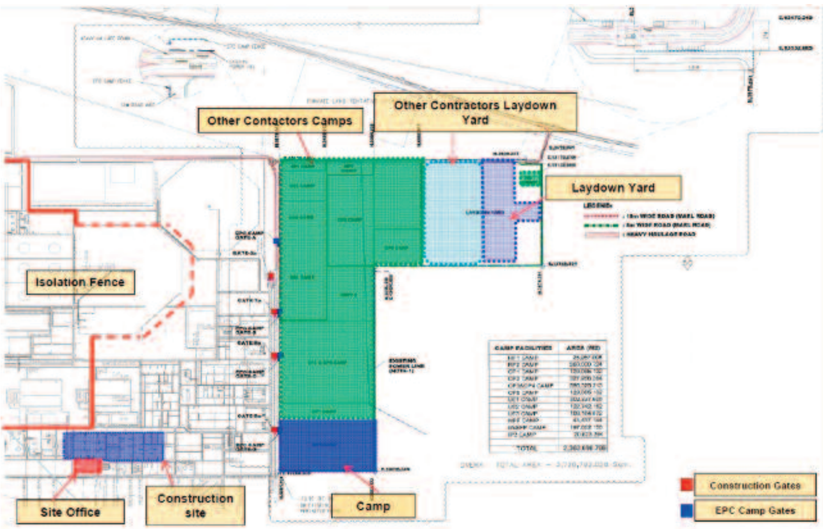
[Table 7.1 - **Summary of principal Constructability Inputs and Activities**]

7.4 Studies to be performed

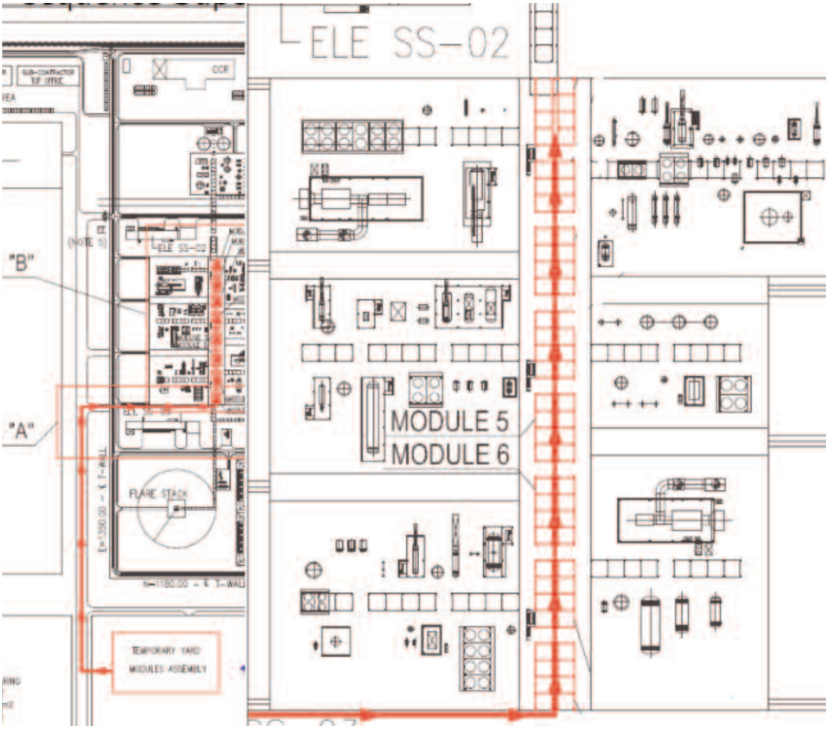
Based on the project phase considered, different types of studies shall be performed.

Here below some examples coming from the preliminary project phase:

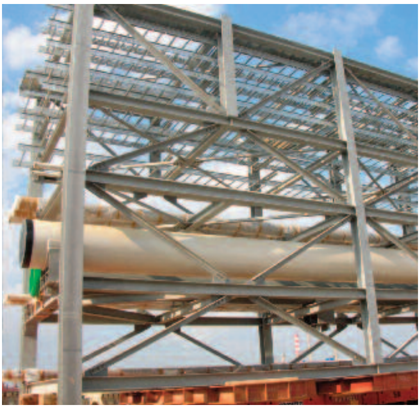
- TCF (Temporary Construction Facilities, see Figure 7.2);
- Accessibility inside the plant (see Figure 7.3);
- Pre-dressing philosophy (see Figures 7.4 and 7.5);
- Lifting plans (see Figures 7.6 and 7.7);
- Schedule review and visual planning (see Figure 7.8);
- Underground networks interferences (see Figure 7.9).



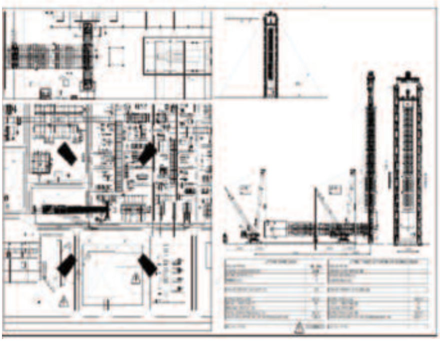
[Figure 7.2 – **TCF Layout (Saipem)**]



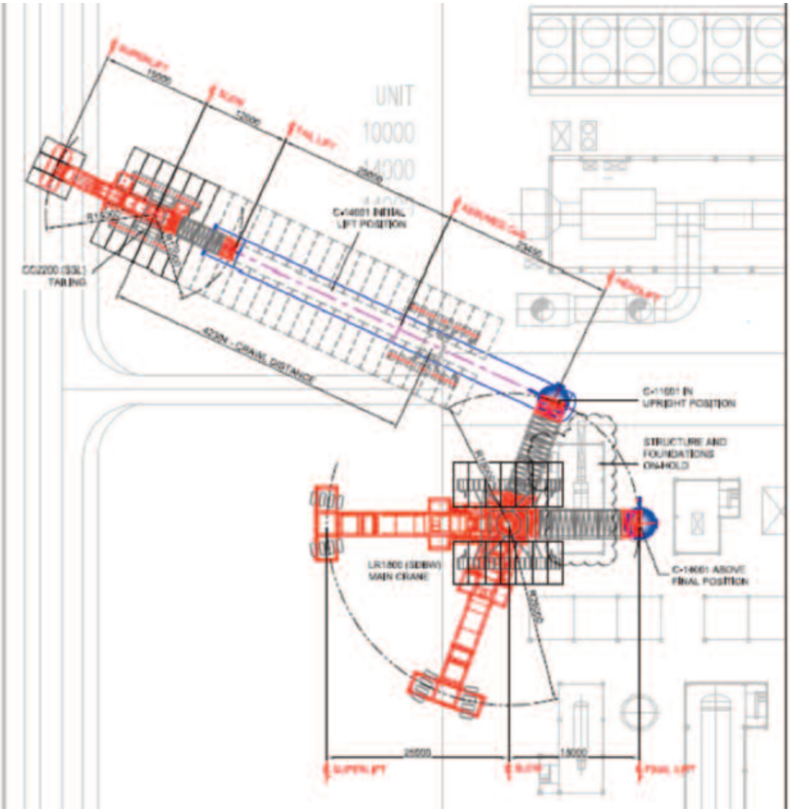
[Figure 7.3 – **Accessibility study inside the plant (Saipem)**]



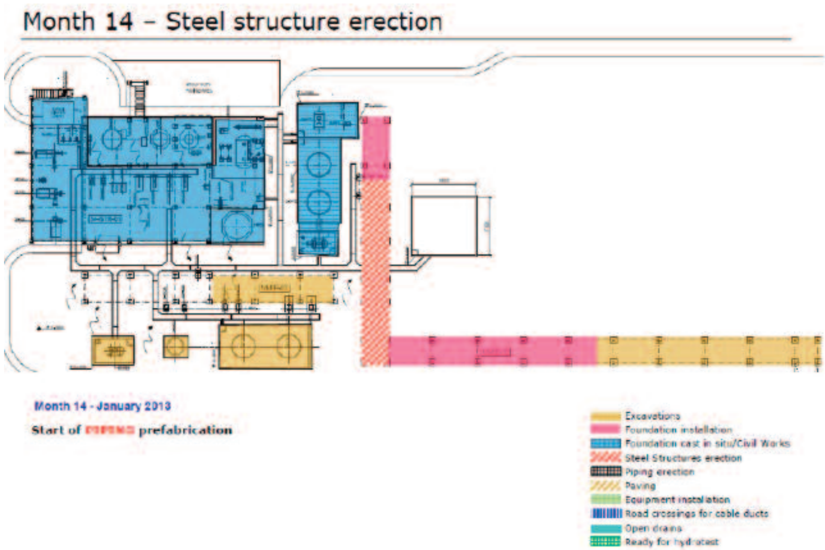
[Figure 7.4 – **Pre-dressed Pipe Rack (IREM)**]
[Figure 7.5 – **Dressed column (IREM)**]



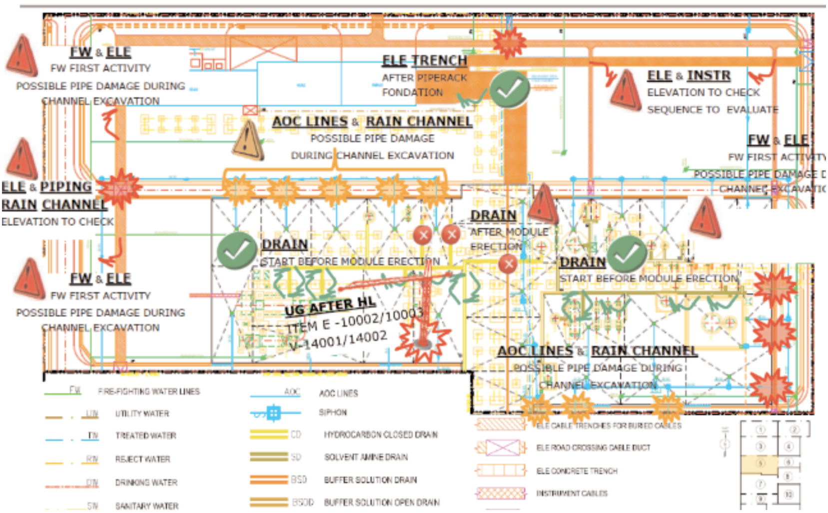
[Figure 7.6 – **Lifting plan (Saipem)**]



[Figure 7.7 – **Lifting plan (Saipem)**]



[Figure 7.8 – **Visual planning (Saipem)**]



[Figure 7.9 – **Underground network interferences (Saipem)**]

8 | Subcontracting

Subcontractors choice is one of Construction phase most critical activity. So being, it does not allow mistakes.

This task mainly concerns EPC Contractor organizations, but Clients may play an important role as well, especially if:

- A subcontracting List is included in the main contract attachment;
- There is a local content clause, in the main contract, requiring employment of national Subcontractors only.

Subcontractors choice shall be based on their ability to perform a specific discipline work, particularly their capability to manage increments in resources during peak periods.

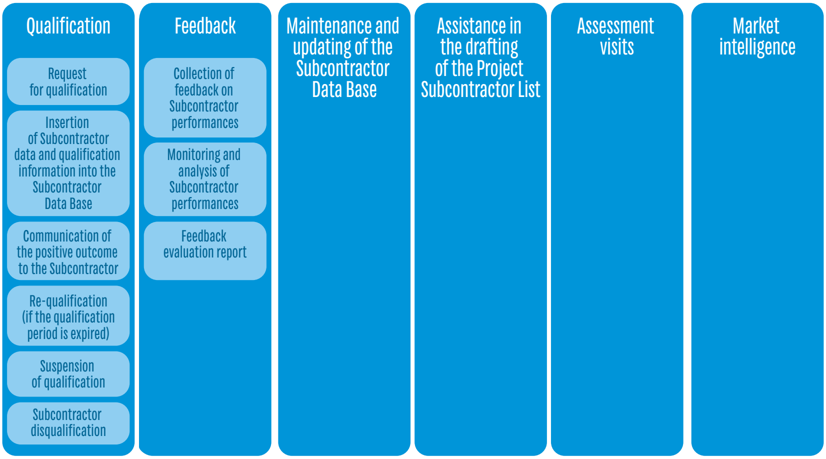
Subcontractors proper management, workforce, construction equipment and financial resources are important factors as well. One of the main risk is that the Subcontractor cannot successfully deliver the work or that it leaves the site before completing the job.

Regardless the origin, these risks must be absolutely prevented, since the consequences will have huge impacts on the EPC Contractor and Client Project targets. The failure of one single Subcontractor can, in fact, jeopardize the completion of the whole Project.

Site Construction Management shall always monitor Subcontractors behavior. If there are doubts regarding their capabilities, investigations have to be carried out even if the Subcontractors have submitted no explicit claims to the EPC Contractor.

8.1 Subcontractor Evaluation and Qualification

EPC Contractors have a Subcontractor management system that includes different processes (see Figure 8.1).



[Figure 8.1 - **Subcontractor Management Process]**

Based on the above, all the Subcontractors shall be qualified in compliance with the EPC Contractor System requirements and processes.

In the Subcontractors qualification process main criteria are considered: Financial & Commercial, Health, Safety & Technical data. Detailed examples are:

- Basic information on the company and the organization management staff;
- Company references and data (type of work carried out, size of the main contracts, direct Man-hours referred to single work, definition of skilled manpower, equipment, etc.);
- Capability to carry out activities related to the commodity codes for which the evaluation is required;
- Execution Plan presented by Subcontractor;
- Subcontractor anticorruption policy and relevant documentation.

Final Subcontractor Qualification decision will be delivered including reasons for positive or negative result and explanation about boundary limits in terms of economic and technical capability.

All this information is generally recorded and updated in the EPC Contractor database for future reference.

Higher number of Subcontractors may increase Health and Safety risks. The article "Mitigating the health and safety influence of subcontracting in construction: The approach of main contractors" (Patrick Manu, Nii Ankrah, David Proverbs, Subashini Suresh, 2013) describes how this effect can be reduced when a subcontracting strategy is in place.

8.2 Subcontracting strategy

Once an EPC Contractor decides to bid and has enough information on the Subcontractor market, it has to produce a Subcontracting strategy.

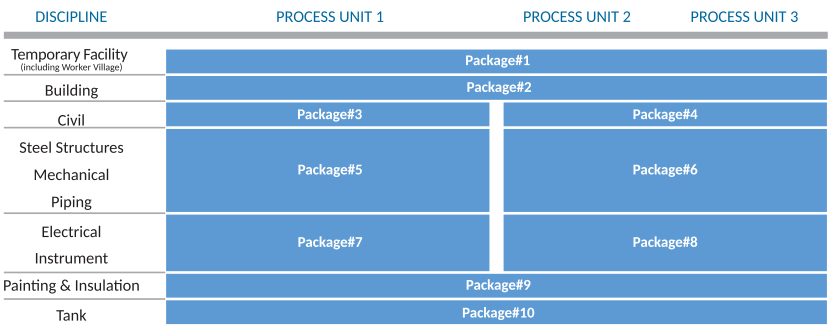
List of possible Subcontractors, usually divided by discipline, shall be available as soon as possible: their Qualification is necessary but not sufficient.

EPC Contractor Construction Home Office and Construction Site Team have to thoroughly investigate Subcontractors ability and capacity.

Methods of conducting this investigation include both visits to Subcontractors offices and operating sites and judgments regarding Subcontractor performances coming from previous Clients.

Branch Manager, supported by the Subcontracting Department, shall look for bank information to better evaluate Subcontractors financial status.

When all the information is available, Construction Work has to be subdivided into disciplines and Work Subcontractor Packages (WSPs), characterized by the overall effort in terms of SMh (for examples of WSPs see Figure 8.2)



[Figure 8.2 – **Work Breakdown Structure (Saipem)**]

WSPs shall be proportioned to possible qualified Subcontractors capacity. Sometimes it is convenient to assign more than one Subcontractor to a single discipline. In fact, even if that approach increases the need of Subcontractors coordination, it also allows possible changes concerning the activities distribution among the involved Subcontractors or even the substitution of those Subcontractors not adequately performing. This strategy is sometimes called dual or multiple sources. If, for certain disciplines, there are no available Subcontractors in the Country, two options remain: Direct Hiring or the look for Subcontractors outside the country.

In some cases, the overall activity can be assigned to one or more General Construction Contractors, capable to handle several disciplines.

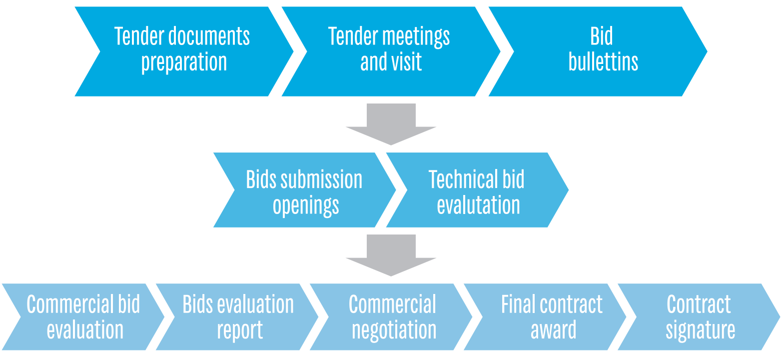
Since General Construction Contractors can directly do only a portion of the required discipline works (may be the more important one like Mechanical Works), Sub-subcontractors are essential to cover the remaining ones. The EPC Contractor, now, has no direct control over Sub-subcontractors, having to process everything trough General Construction Contractors.

In this situation benefit coming from the cost saving related to the EPC Contractor supervision activity must be carefully analyzed in order to balance the consequent loss of direct control.

8.3 Subcontract Package award process

Qualified (or to be qualified) Subcontractors may be invited to produce offers during the EPC Contractor bidding phase (this preliminary activity will not be considered in this book).

Once the EPC Contractor gets the job and Subcontracting strategy has been confirmed or amended, Construction Site Team, in cooperation with Construction Home Office, shall prepare all the tender Subcontracting documents to send Request For Quotation (RFQ) to each Subcontractor. To better understand the Subcontract award process, readers can refer to Figure 8.3.



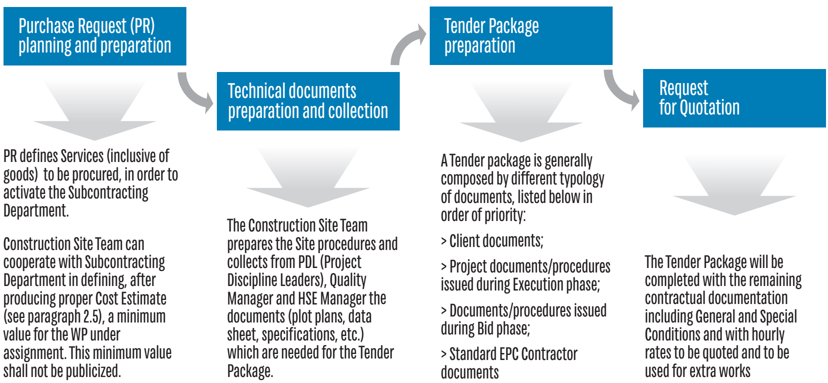
[Figure 8.3 - **Subcontract award process]**

The Construction Home Office is not involved in all the above phases. Its involvement is limited to the tender documents preparation, tender meetings, bid bulletin and technical bid evaluation. The other phases are managed by the Subcontracting Department.

The process mentioned above is performed for each WS package identified in the Subcontracting Plan.

8.4 Tender Package preparation

For each Package, identified in the Subcontracting Plan, the following process (see Figure 8.4) shall be implemented:



[Figure 8.4 - **Tender Package Preparation**]

A tender package is structured as follows:

- Scope of work;
- Preambles and BoQ;
- Subcontracting programme;
- Project Organization;
- Temporary Construction Facilities;
- Heavy Lift;

- Site Procedures;
- Mechanical Completion Procedure;
- HSE Procedures;
- Quality Procedures;
- Technical Specifications and Drawings;
- Material and equipment vendors' documents.

The process is considered completed once the Request For Quotation (RFQ) is issued by the Subcontracting Department. The RFQ is a document, sent to Subcontractor Bidders, requiring the submission of an Offer for the Services and Goods requested. The offer has to be split in two parts: technical and commercial.

[Figure 8.5 – **Drilling Tower Module lifting and skidding with elevator system for Scarabeo 8 Saipem Platform in Fincantieri Palermo (Fagioli)**]

8.5 Technical and Commercial Subcontractors offer evaluation

All offers shall be sent, by the bidders, in two envelopes containing the following:

- The first one: all economical and contractual aspects to be processed by the Subcontracting Department;
- The second one: all requested technical information to be processed by the Site Construction team.

As soon as the Technical Offers are received, Site Construction Team, supported by the Construction Home Office, shall analyze the documentation provided by the Bidders concerning:

- The suitability of the Bidder's organization;
- Key Bidder personnel CVs (i.e. Project Manager, Site Manager);
- Work procedures and specific Method of Statement for unconventional operation;
- Subcontracting plan (if any);
- Direct construction man-hours and Manpower Deployment Schedule, split by trade (see point 2.5.4);
- Indirect man-hours;
- Vehicles and construction equipment list required for the project with proper maintenance documentation;
- Mobilization and demobilization plan;
- Temporary Construction Facilities layouts in compliance with site availability and utilities request as per bid indications;
- Bidder's Quality Site and Home Office Organization Charts;
- Bidder's HSE Site and Home Office organization charts and related Policy Procedures;

In some cases, technical Subcontractor offers are systematically evaluated based upon specific parameters. Each parameter has a precise percentage incidence on the overall evaluation.

Both parameters and incidences can vary according to the type of contract, scope of work and/or Specific project requirements.

After setting the parameters, the Construction Site Team shall issue the technical bid evaluation containing:

- A summary indicating acceptability/unacceptability of each Bidder and the relevant final score with notes providing a brief description of the bid history;
- Technical analysis of each bidder.

At the same time, the Subcontracting Department takes care of all the economical offers. They produce a sheet to properly compare all proposals among them.

The two evaluations, Technical and Commercial, lead to the contract closure between the Client and the awarded Subcontractors.

Clarification meetings, if necessary, may take place until the final decision has been made.

[Figure 8.6 – Reactor lifting Meg Project Singapore Foster Wheeler with Towers, Strand Jacks and Crane (Fagioli)]

9 | Construction project control

Construction is a complex and difficult process due to a huge amount of possible reasons. In order to cope with this situation, the first and most important element to control the Construction is the perfect understanding and measurement of the actual Construction progress compared with the planned.

Many activities often emerge as under-estimated in terms of actual effort compared with the estimated one. This is generally due to scope of works changes, bad Subcontractors scheduling performances, troubles dealing with suppliers, etc.

For these reasons, a proper monitoring and control process is required in order to promptly take effective mitigation actions.

In the next paragraphs, technicalities that shall be used to monitor construction progress are presented.

9.1 Physical Progress Measurement Methods

Since the Construction Plan is built using SMh, the same parameter shall be used in Physical Progress Measurement.

All activities performed shall be transformed in Earned SMh using the SPR (see paragraph 5.2).

As Earned SMh it is intended the percentage of actual work evaluated in terms of corresponding SMh compared to the total amount of budget SMh (see PMBOK 2014).

This conversion comes quite easy for the parts of the Construction phase already completed and tested. It is more difficult referring to work-in-progress ones since is much more difficult to measure explicit intermediate milestones.

Nevertheless, the work-in-progress activities cannot be disregarded, since the corresponding SMh value shall be compared with:

- Original Construction Plan (to evaluate schedule performances);
- Actual Direct Man-hours (for Productivity Measurement).

Usually the work activities are divided into milestones with related standard weights generally coming from Company previous experience.

Some examples are the following ones:

- Concrete and anchor bolts, subdivided in: formwork, steel bar preparation and assembly, anchor bolt positioning with template, checking, pouring, curing;
- Piping Prefabrication, divided in: cutting, bevelling, joints tack welding, welding, X-ray and other testing, touch-ups, storing;
- Equipment installation, divided in: level plates positioning, lifting equipment preparation, transportation in lifting position, lifting, bolting, alignment checking, lifting equipment standard operation restoring.

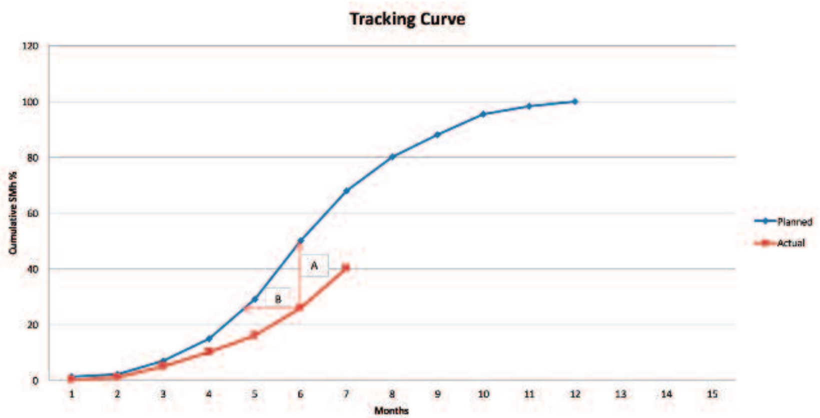
The Construction (and Project) progress is measured as shown below:

$$Progress = \frac{Earned\ SMh}{Total\ Planned\ SMh}$$

If the Construction Cumulative Progress is drawn in a time scale graph the corresponding diagram can assume an S shape (S curve). If the Construction Periodical Progress is drawn in a time scale graph the corresponding diagram can assume the shape of a bell (Bell curve). The S curve represents the integral over time of the Bell curve.

Indication about the Project Construction Progress can be deduced comparing the Actual Progress curve with the Planned Progress one. These curves can be traced by area, discipline, Sub-contractor and, of course, the overall Construction Progress.

For a specific unit of time the delay in terms of Earned SMh and forecasted SMh can be measured along the y-axis (segment A) while the delay in achieving a specific percentage of the progress can be measured along x-axis (segment B) as the difference between actual progress and planned progress (see Figure 9.1).



[Figure 9.1 – **Overall Construction progress curve]**

9.2 Physical Progress Review

Usually Progress measurement is repeated on a monthly basis but it can be done on a weekly or even a daily one if it is required.

By the usage of specific software, the measurement and periodic updating of the Construction Progress can absorb few resources even if associated to each single activity: this is the base for any sound Site Construction Management.

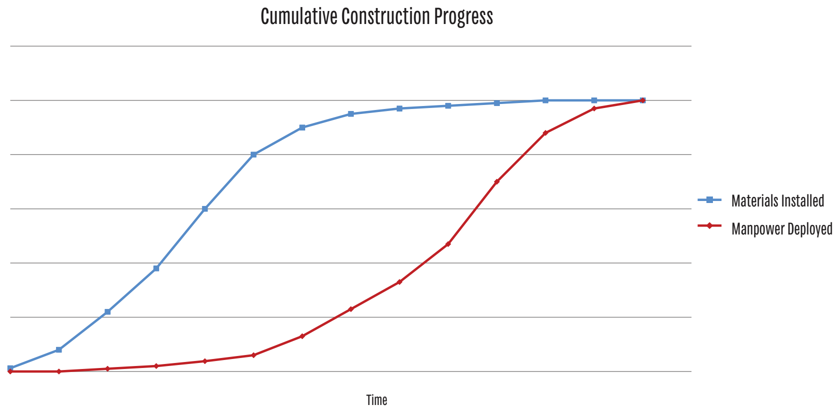
During Revamping Plant Projects for example, when the maximum out of service time allowed is no more than 6/8 weeks, the time unit scale of the Construction progress updating is one day.

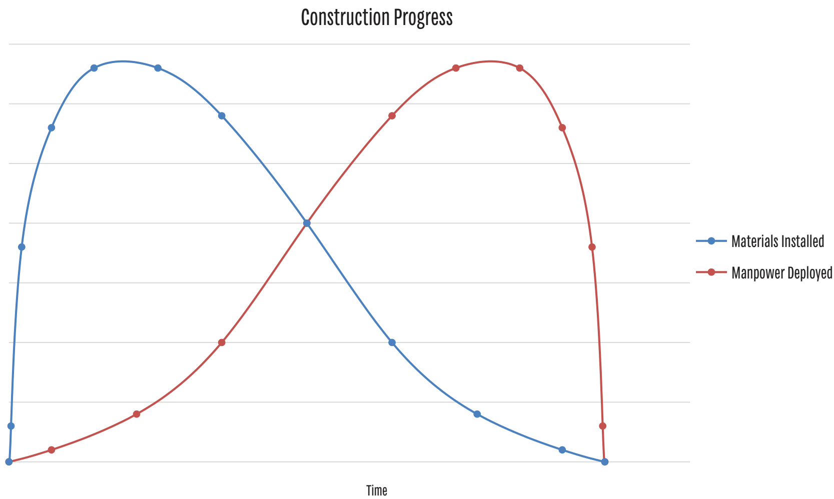
When substantial delays are detected, the Construction Site Team has to promptly investigate the related causes in order to identify and decide proper actions to be implemented.

9.3 Comparison between Progress Measurement Methods

Measuring the Construction progress on the basis of quantities installed with respect to total quantities estimated, can bring more often to an over estimation of the Construction Progress (see Figure 9.2).

At the beginning, it is logical to give priority to the bigger parts of the plant (like big foundations, heavy equipment, large bore piping) and so progress looks good. In the following period with the same crews, progress will not be comparable and delays will become inevitable.





[Figure 9.2 – **Materials installed and Manpower deployed during Construction activities curves**]

The proper unit to be used in progress measurement is the Man-hours one. It represents the real Construction potential considering actual Manpower and equipment deployed.

Direct Man-hours are an option but the Standard Man-hours are preferred in some conditions for the following reasons:

- SMh are calculated with the use of Standard Outputs. They rely on the same criteria and once defined, they are stable, exception made for rare exceptional cases. This reduces the possible overestimation or underestimation of each activity;
- Direct Productive Man-hours (DPMh) introducing the Productivity, that can change in the same area along the Construction Project lifecycle increase difficulty in their actual evaluation introducing overestimation or underestimation of each activity;
- The Construction progress can be also evaluated in terms of amount of actual cost, respect to the budget one, and this way of measurement is preferred at top management level. Despite this fact, SMh has no direct relation with costs, which include the value of infrastructure and material but mainly are subject to change due to currencies exchange, inflation and exchange rates variability.

9.4 Critical Work Package Progress

Sometimes, as part of the general Planning, there are Critical Work Packages, which need more detailed planning and control activities. This can be obtained issuing a more detail approach with the same tools mentioned before (BoQ, SMh, SPR, DPMh and AMh).

This more detail approach is generally related to a higher value and higher criticality of the work package control.

9.5 Productivity Measurement and Analysis

To measure actual Productivity, it is necessary to know the DPMh spent by Construction Subcontractors and Direct Hiring (DH).

Considering the operative point of view, it is very difficult to get the DPMh amount for any single activity or for a specific site area and sometimes even for main activities (e.g. excavation, concrete, piping/supports prefab/erect, steel structure erect, cable trays/pulling, cables termination, ect). Subcontractors' data, generally, has not the same structure of the EPC Contractor data and requests.

Such situation brings to the usage of the overall number of workers registered daily on site as the basis for approximation of the overall Actual Productivity bearing in mind Direct/Indirect and Productive/Unproductive concepts (mentioned in paragraph 5.1) as good. Having the list of people operating in each working day, the number has to be multiplied by average worked hours.

Actual Productivity Factor, K2 is calculated with the following formula:

$$K2 = \frac{AMh}{SMh}$$

where SMh are the ones achieved by the same amount of people and in the same period of time of DPMh.

K2 is not constant over time. It changes due to several reasons. For example, it will certainly improve once the same activity is repeated several time (learning process) or if the same crew is employed together for quite some time, but it is then important to update all K2 factors records and possibly their trends along the Construction phase. They will be used to tune the K1 factor deployed in the following revised Construction Plan.

As already mentioned in paragraphs 5.3 and 6.5, Productivity Factor can be sometimes computed as the inverse of the one presented here (that is the ratio between SMh and AMh).

9.6 Combined evaluation Physical Progress/Productivity

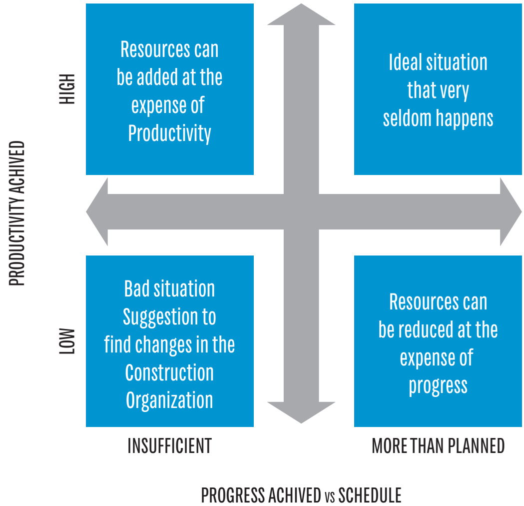
While EPC Contractor Site Managers and Construction Managers ask for Progress Reports they also require Productivity Reports as well, although in most cases they can only count on internal data.

It is a mistake to think that, if the contract has a Lump Sum clause, Productivity is a Subcontractor obligation only.

One of the common mistake emerged in those situations when the Construction Progress registers bad performances is to consider an increase in manpower as the main option (as said in paragraph 6.7). The consequence of this mitigation action can be inadequate or even counter-productive (see Figure 9.3).

Under unfavourable conditions, the increase of manpower produces Productivity loss (for instance due to increase of density as for paragraph 6.6), which overcomes the benefit coming from the increase itself. The same reduction can be observed when double shifts are in place to recover planned progress since the nightly productivity in lower than the daily one.

The immediate results are evident additional costs without any operative improvement of Construction performances.



[Figure 9.3 - **Productivity vs progress matrix]**

9.7 Construction phase Crisis of Activities

A Project can be considered in a critical situation when standard and exceptional actions are not enough to produce improvements that would conclude the work on time (or very close to) and/or within the budget (or substantially close to the budget).

The main reasons are the following.

- Major faults discovered in the main equipment and machinery;
- Organization architecture of the Project, EPC Contractor and Subcontractors, is not efficient and Managers are not adequate;
- Important delay in the arrival of major equipment or lack of bulk material. This situation can be attributed for instance to Fabricator default which impedes completion of fabrication and leaving workshop;
- One Subcontractor is in bankruptcy;
- Serious safety problems (death accidents) are requesting a full revision of organization and schedule of Construction.

There are premonitory signs to help foresee possible critical situations, the following.

- If a delivery of a major equipment or bulk material has been delayed by strikes it is possible that quality is not acceptable;
- Budget frequent revisions can anticipate possible overruns;
- Subcontract Manager leaving the company is a sign of possible future problems;
- Documentation that has been delayed without apparent reasons can indicate that a defect has been detected;
- Subcontractor delaying salaries payment is an alarm bell of possible financial problems.
- Subcontract personnel removal from the job

When a Project is already in a critical situation, Project and Site Managers have to take specific actions. The following.

- A general check on the status of the Project. If it is considered important a Cold Eye Review procedure can be activated;
- Based on of the check activities done it can be produced an accurate prevision on the most likely completion date using only current possible actions. The completion date together with a revised budget issue are the elements to confirm or not the crisis status of the Project;
- If the crisis is ascertained Company top Managers have to be informed;
- A strategy shall be defined and approved at top level indicating all extraordinary actions to be implemented and which one is the preferred direction between the two: delivery time reduction or costs reduction, or both;
- Only two or three plans at most have to be considered as possible options;
- Responsibility actions – internal and external – have to be organized in parallel;
- Final decision has to be reached choosing an option which indicates new targets together with all consequent organisational modifications, additional resources and costs;
- The crisis status together with the remedial actions shall then be communicated to Client and to all parties involved. Client shall recognize that situation of the Project is serious and remedial measures are reasonable.

Possible remedies to recover from critical situations include the following.

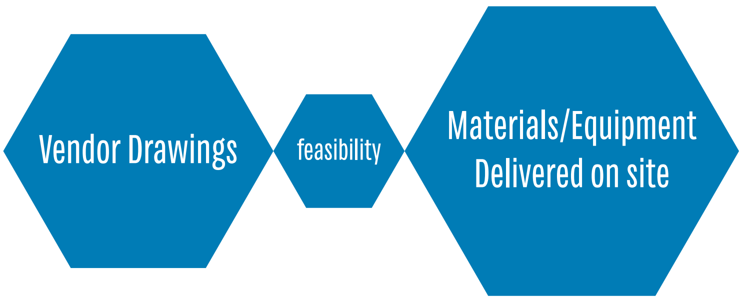
- Temporary suspension of a part or the whole works;

- Variation in the project architecture like distribution of tasks among existing organizations and/or insertion of new organizations;
- Variation in the Project team and substitution of persons covering key position;
- Introduction of incentive scheme;
- Improvement or changes in the engineering resources;
- Introduction of new suppliers or substitution of some of them;
- Introduction of new transportation organizations with new systems;
- Increase overtime or introduction of shifts in Construction;
- Introduction of new Construction Contractors, substitution or reduction of scope of some Subcontractors;
- Changes in the Pre-commissioning or Commissioning programme.

An alternative list of possible solutions, that can be implemented to recover a project from a critical phase, are presented in the article "An Effective Disaster Recovery Model for Construction Projects" (Leonidas G. Anthopoulos, Efrosini Kostavara, John-Paris Pantouvakis, 2013). Studies performed in the article are inspired by disasters occurred during several past Construction Projects,

9.8 Construction Feasibility Analysis

Construction Feasibility is a proactive approach for planning and monitoring. It allows verifying the match between Drawings and Materials required on the field to perform activities according to the sequences and priorities set by the construction schedule. Ultimately it guarantees work fronts, progress and efficiency in construction (see Figure 9.4):



[Figure 9.4 – **Construction Feasibility concept]**

This system can be applied to any discipline (i.e. civil, piping, electrical, instrumentation, etc.), even though the activities using large quantities of bulk are the ones actually obtaining the biggest benefits, in terms of:

- Ability to check the original erection activities planning versus the actual chance to set it in motion (that means improvement in site activities planning and progress control);
- Prediction of available work front reducing men and equipment downtime (that means great improvement in construction cost saving);
- Improved subcontractors' management (that means reduced resources dedicated to planning and work front management).

The Construction Feasibility analysis must proceed identifying the specific quantities as shown in Figure 9.5.

FORECAST QUANTITY	Last update of Construction quantity based on BoQs (Bill of Quantities) assessed by Engineering Function
FEASIBLE QUANTITY	> Value defined by Engineering Function (maximum can be equal to Forecast Quantity), further confirmed on site by Field Engineering Manager, in terms of theoretical quantities that can be erected > Such quantity is defined on the basis of Drawings Issued for Construction and/or Materials (excluding the quantity on Hold) Delivered on Site
ERECTABLE QUANTITY	> Value defined by Construction Manager (maximum can be equal to Feasible Quantity), in term of quantities that can be really erected on time > Are not concurring items that cannot be worked-out due to Access/Accessibility issues, Work Permit issues, adverse impact of other field activity (e.g. portion of piping circuit cannot be field erected since the structure is not mounted, equipment cannot be positioned in place since the foundation is not ready for loading, etc.), and due to any kind of field restrictions excluding resources
NET WORK FRONT	> Value defined as the difference between Erectable and Actual Quantity (Performable and Actual Quantity during Mechanical Completion and Precommissioning phase) > It is the quantity on which it's possible to set and upgrade the mobilization/demobilization of workforce

[Figure 9.5 – **Construction Quantities**]

Being part of the Constructability system, Construction Feasibility analysis is organized according to the Work Packages defined in the construction planning phase. It can be defined for large packages or rely on very detailed portion of the plant, according to the level of criticality of the activities.

The Construction Feasibility system is not a single procedure of the Contractor but it is a set of working methods that involves all the branches of the Contractor. In fact, it requires:

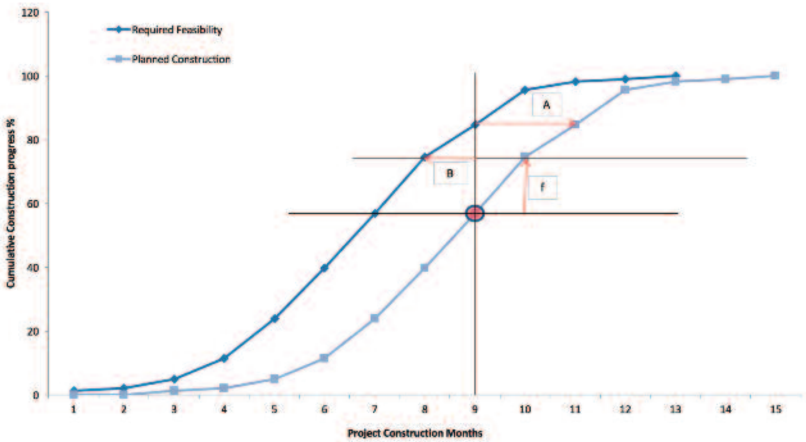
- The Design team to set engineering deliverables and material identification in a clear manner and to draft them in an early stage;
- The Planning and Construction team to set priorities, through the level 3 planning and the critical Work Packages;

» The Procurement, Expediting & Inspection and Logistics team to give clear feedback about the delivery of the overall material of the critical WPs.

Construction Feasibility can be expressed in construction units of the related activities (volume of concrete, weight of pipe, etc.) or percentage progress of the related activities with related Standard Man-hours. In any of the mentioned units, Construction Feasibility is shown as a cumulative curve compared to the cumulative curve of the planned construction activities (see Figure 9.6).

Cumulative Construction Feasibility is the Sum of each single Construction Feasibility contribution.

The starting time of the Construction Feasibility curve, that is the curve referring to materials availability on site, is one month before the beginning of construction activities.



[Figure 9.6 – The Construction Feasibility S curve]

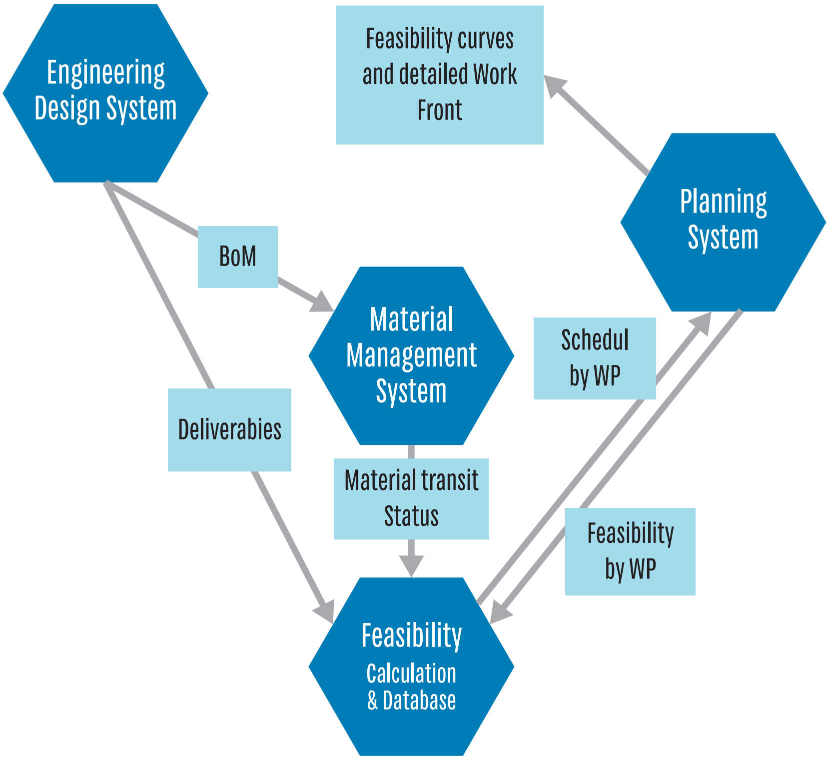
In Construction context materials are intended as the complete set of items (single component or complex piece of plant equipment i.e. package with its consumables and special tools) required to perform a specific construction activity and contribute to completely erect ("complete mechanically") a portion of the plant. The list of materials is defined by the "issued/approved for construction" drawings (i.e. erection instructions valid for construction). The sooner the list of materials is defined in the drawing, the sooner the materials can be procured and made available on site. The process of matching materials and drawings is generally automated in the modern material management systems. This provides that:

» Drawings are uniquely coded and their status is as well identified in a coded manner;

» Material list (Bill of Material) can be uniquely linked to the respective drawing;

- Materials are coded according to Contractor or Client standards, any item can be uniquely identified and the supply status can be known and even predicted for instance when a component reaches the site;

The overall workflow is described by Figure 9.7:



[Figure 9.7 – **The Construction Feasibility Work Flow**]

- The drawing is defined by the Design discipline;
- The related BOM is built and linked to the drawing;
- Material is purchased;
- Material expediting information about material status of transit (actual and forecast);
- Construction Feasibility predictions can be run based on the material status predictions;

- Material start reaching site;
- Construction Feasibility analysis can be run to check the actual availability of work front.

Without a proper Construction Feasibility analysis, Client and EPC Contractor Construction Management shall be concerned that Construction Subcontractors and Direct Hiring could be in the impossibility to go ahead with the work.

9.9 Changing priorities in closing to Commissioning

The rationale that defines the best sequences for the Construction Activities is generally different from the rationale that defines the best sequences for Commissioning Activities.

When Construction Progress approaches the first milestone of the Mechanical Completion (usually around the 70% of total progress) the priorities shall be changed according to the Concurrent Engineering strategy (see paragraph 2.3).

Before reaching this limit, Construction arranges the work maximizing the discipline activities in the same area due to Productivity reasons.

For instance, it is possible to have a higher output by taking care of all the lines that are in the same reach of a crane instead of following a specific pipeline till completion. This reduces the need to move construction equipment around.

This approach can be accepted and promoted until it is necessary to Pre-commission and Commission a specific system. To do so, in fact, the same system needs to be fully finished and tested.

The passage from one rationale (Construction) to a new one (Commissioning) shall be always properly planned.

Obviously the best Project Execution emerges from the optimal synergy between Construction and Commissioning Activities.

9.10 Quality control and Final Project Documentation

Quality is a fundamental activity during the construction phase. There is no progress if the quality does not go along with the construction.

According to Quality norms, any part of the Project, in order to reach the "Mechanical Completion" to be transferred to the Commissioning Team, has to be equipped with proper documentation. Every single component shall have a proper file. Every file shall include any kind of certificates of origin, testing certificates, descriptive documents.

If this operation is not properly organized in advance it will be very difficult to be done in time.

Client and EPC Construction Management Team shall be aware that maintaining Completion Time is not only a matter of physical quantity installed but also papers and/or electronic documentation.

[Figure 9.8 – Load out project of a module]

10 | Construction cost, estimation and payments

There are several methods to produce Construction Cost Estimation. They can either rely on internal methods, or trust on approaches Country specific.

Whichever the selected approach is, in order to validate and verify both the project scope and the subcontractor quality, EPC Contractor shouldn't accept esteems produced by local companies (based on their own procedures and approaches) comparing them with internal values and standards.

Even asking locals to produce estimates according to an EPC Contractor standards does not represent a best practice and generally brings to unacceptable results.

Usually, in fact, local companies are not capable to quickly understand and master unknown methods.

Completely different considerations regard Payments. In this case, in fact, it is generally better to refer to the EPC Contractor techniques, since they can be easily explained and accepted by Local Companies.

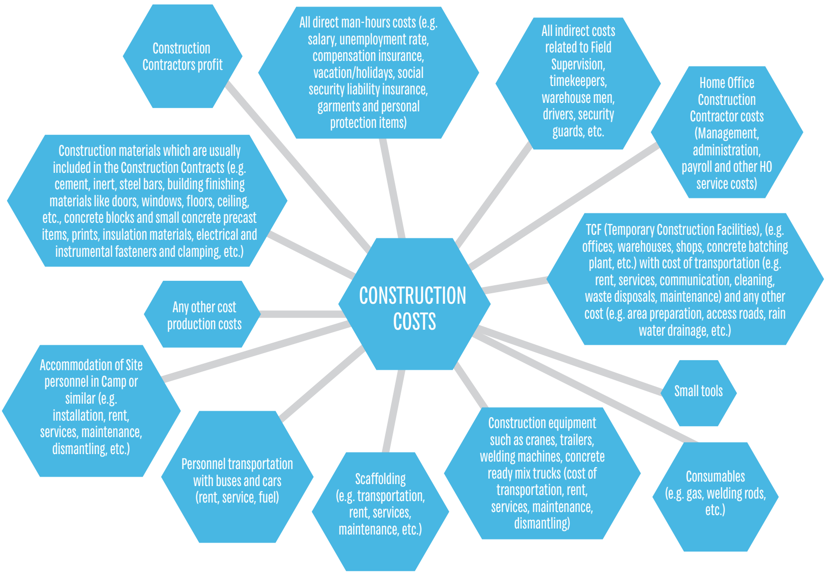
10.1 Estimating in Early Phases of a Project

Construction Cost estimation is mandatory in the early phase of the Project from both Contractor and Client point of view. It shall be based upon Client and EPC Contractors internal sources referring to the maturity level of project definition and estimate input information (quantities, schedule, project data, specific requirements)

In Chapter 5 the evaluation of Construction activities, using SMh and related DPMh, has been explained.

Approaching Construction Costs, it is important to keep in mind Indirect and Unproductive Man-Hours to be accounted for as well, along with Construction Materials, Consumables and Utilities.

Examples of most common Construction Costs are presented below (see Figure 10.1):



[Figure 10.1 - **Construction Costs**]

There are several ways to catalogue Construction Costs. Usually, each company has its own, based on past experiences and the adoption of specific software solutions. Moreover, some companies may sign specific contracts where equipment and material costs are merged with erection ones (like Power Units, Construction Tanks and Steel Structures), further increasing the Cost Estimation process complexity. It becomes evident, how difficult it is to have a clear and transparent picture of the project costs along the overall project life cycle.

Avoiding big misunderstandings in the project cost evaluation is really hard, as well due to the completely different internal cost classification among project stakeholders.

To ease Construction Cost estimation, usually, Clients and EPC Contractors refer to three basic categories:

- **A.** Direct Costs;
- **B.** Indirect Costs (Supervision and Management Costs);
- **C.** Materials Costs.

All detailed elements represented above are computed as percentage of these categories. It must be noticed this division is not rigid: most items (truck drivers, foremen, etc.) can be in fact considered as part of two different categories or even all three of them.

As any other budget, Construction Costs Estimating shall include a percentage (depending on the type of the project) for contingencies to cover possible unforeseen extra costs, strongly influenced not by only the main contractor strategy but also the contract type.

Deeper analysis on cost estimate can be found in the article "Cost simulation in an item-based project involving construction engineering and management" (Jui-Sheng Chou, 2011). The article, first of all outlines a simulation methodology to better evaluate construction cost, then it illustrates the outcomes of the simulation applied to paving construction cases.

10.2 Estimating for a binding bid

As described in chapter 8, when an estimation is requested for a binding bid, an EPC Contractor requests and relies on binding offers produced by Construction Subcontractors.

In this case Direct Costs (A) and Material Costs (C) will be mainly replaced by the offers received from Construction Subcontractors. The biggest obstacle lays now in the common understating of the tender requests. Since an accurate bid requires time to avoid both under and over budget allocation, the available time for the cost estimation is the "big enemy".

In this initial phase of the project, the estimators should also have a huge knowledge of the rules adopted internally and by subcontractors regarding the quantity surveying. This point, in fact, represents the main driver for cost estimation (see also paragraph 5.2).

10.3 Costs Evaluation and Checking after a Project becomes operative

The Construction Budget needs to be revised and updated when changes in the Project Scope occur during the negotiations before the contract signature.

This phase is very critical due to the short time available (generally few weeks) for the client and the main contractor to take important decisions that will impact both the execution phase (that lasts from 3 to 6 years or more) and the exercise phase of the plant (that lasts from 20 to 40 years or more). The risk of misunderstandings among the parties involved also contributes to increase the sensitivity of this phase.

Due to these considerations, all previous estimates have to be revised after the EPC Contract signature. The updating phase will take place after the signature of each Subcontracts as well.

In this process, contractual contingencies can be reduced as the signed contracts are progressively replacing the estimated values.

[Figure 10.2 – Jasmine Jacket load out by skidding operation in Rosetti]

10.4 Checking Construction Contracts Costs during Site Operation

As soon as any Construction Subcontractor starts production, it is necessary to monitor the actual productivity (K2) as indicated in paragraph 6.4. The K2 parameter has to be compared to the K1 supposed by the Subcontractor at the beginning of the work. Possible reasons for discrepancies are:

- Absence of a previous experience on specific activities;

- Poor level of experience of direct manpower resources;
- Different composition of the work force compared to the one established during the contract signature;
- Severe weather condition;
- Management capability;
- Different construction equipment.

All the above must be checked and improved upon, if necessary, in order to obtain the best Subcontractor performance.

Due to the learning process K2 initial values usually appear higher than the average. It is then advisable a continuous control in order to obtain a stable and robust evaluation of the actual productivity of the involved work force. Usually this check lasts at least one (sometime two) month(s).

Any change, no matter the cause, can lead to extra costs, which must be compared to the original forecasted outcome, based on previous underestimation of specific cost accounts.

This situation can in fact lead to legal processes (e.g. a claim) from the Subcontractor to EPC Contractor.

Delays or the output quality may instead generate claims from the EPC Contractor to the Subcontractor.

Subcontractor costs have to be revised and compared to the budget. Experience suggests that an accurate control of the situation helps avoiding or at least anticipating possible claims or extra costs. As already mentioned, low Subcontractor performances can be managed by a continuous and rigid control of the related activities. Sometimes it is even possible to reduce the related project scope reallocating part of the work to another Subcontractor.

10.5 Site Supervision and Management costs

As previously mentioned Site Supervision and Management costs are part B of the Construction Costs (see Paragraph 10.1).

They are subject to continuous changes along the construction phase to cope with new situations that modify the original drivers used to produce this estimate.

Summarizing, they mainly depend on changes in:

- Planning of Construction Activities;

- » Composition of construction activities;
- » Specific (unitary) costs of the various components.

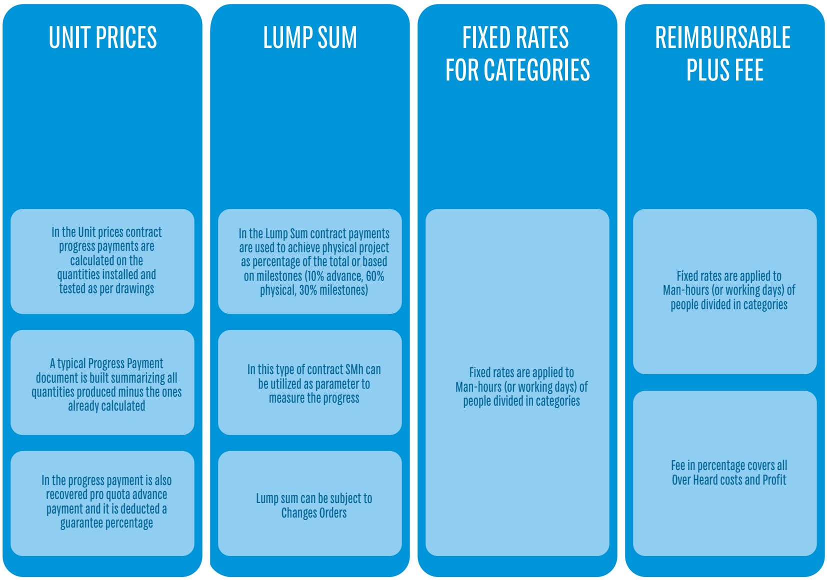
10.6 Progress payments

Progress Payments conditions (see Figure 10.3) are defined in the Contract. They can be classified, for example, as per systems used to pay their services.

In some Construction Contracts a clause concerning double currency payments can characterise the contract itself (for instance local currency and US Dollar). Progress Payments have to comply with this clause as well.

The EPC Construction Cash flow profile can be computed in advance to check upon critical periods of the construction phase. These situations must be carefully analysed in order to properly manage the financial support coming from the headquarter and Subcontractor payments (with direct consequences on their operative management).

Direct Hiring Contract is usually easier in term of payments since can be firmly related to the SMh achieved.



[Figure 10.3 - **Progress Payments]**

At the end of any Construction Contract, a Final Economic and Financial Progress profile is produced. It represents the overall economic value received during the project execution. In this phase, discrepancies between the Client economic evaluation and the Contractor ones are possible. If that is the case, formal and informal agreements as well as meetings between the parties involved (Client and Construction Contractor, Construction Contractor and Subcontractor) must be held to avoid legal consequences during the project closure phase. When the mediation process is not enough to reconcile all the parties, the offended one can submit a claim. This claim must follow the specific guidelines included in the signed contract.

10.7 Relation between Progress and Payments

Payments and forecasted payments estimates are usually registered and judged by the Cost Control team, as part of the overall Construction Control Duty.

The Construction Budget, as a part of the Project Budget, shall be continuously updated and controlled, since a strong and direct relation exists between actual Construction Progress and Actual Payments.

Contingencies absorption, if proceeding in regular way, can be considered quite normal. Since the contingencies are defined at the beginning to cope with uncertainty and increase the overall cost of the project (decreasing the probability to win the bid) their correct absorption give evidence of initial understanding of contract difficulties (so declare the experience of the contractor).

In case of complications or unforeseen situations, the Site Manager and the Project Manager have to discuss and jointly find a proper solution.

10.8 Penalties and liquidated damages

Almost all Sub-contracts have a "Penalties" or "Liquidated damages" clause in case the work is not completed on time. A percentage of the contract value will be considered for any day of delay in delivering the work. The maximum value applicable is usually 10% of the overall contract value.

Further detailing, it must be noticed that "Penalties" are different from "Liquidated Damages". The first one is a pecuniary payment stipulated as "in terrorem" of the offending party. The essence of liquidated damages is instead a genuine and reasonable estimate of the loss and damage suffered by the Contractor (or the Client).

It is advisable to use always the term "Liquidated Damages" in order to avoid problem, especially in contract where the applicable law is the common law (used in UK and USA influence areas).

Site and Construction Managers know that any "Penalty" or "Liquidated damage" registered is related to a specific amount of money the Subcontractor will have to pay to the Main Contractor (at the same time, the Main Contractor has to pay to the Client). Usually this amount only covers a very small portion of the damage suffered by the EPC Contractor. That is why these clauses are only a deterrent for the Subcontractor.

The only true valuable target the EPC Construction Management aims to, is avoiding any possible delay since they generate extra indirect costs connected to the project duration as well as possible penalties and liquidated damages to correspond to the client. Therefore, it is always better for a Construction Contractor to correctly support and help all Subcontractors before a delay occur rather than receiving payments from them.

[Figure 10.4 **– Load out project of a module]**

11 | Lesson learned process

Usually, EPC Contractors get feedbacks from the work already carried out through formal and informal channels. This process must be strongly formalized along the project execution. At the end of the project, in fact, people involved are not interested in producing reports on what has been done since, by that time, their importance is not so evident. The common tools used to drive the experience from the site to the home office departments are:

- Analysis of the Construction Objectives for the project;
- Close-out Reports;
- Constructability lessons learned reports.

11.1 Relationship between Home Office and Site

EPC Contractor Project Organization concerning Construction can be briefly described as follows.

Site Management team will be brought up to life as Contract obligations become effective. Site or Construction Manager and part of his staff begin by working in the home office. Nominated Site Manager most likely supports the Proposal Manager activity during the bid preparation and the final part of the negotiation with the Client (jointly with the Construction Home Office Department).

It is very common that the Site Manager is not immediately available or present in the main office for a new contract negotiation, being engaged mainly in the final phase of another (ending) project.

For this condition, for the ending project, it is necessary to define a proper transition phase establishing how long the Site Manager has to be present on the ending project site, to start working in the new project.

During a long internal and external negotiation process, the main decisions to be taken are:

- The identification of the new Site Manager for the ending project to allow the previous Site Manager to move to the new project. Usually the best solution is to decide in favour of his Number 2 who knows perfectly the true story of the project and day by day decisions taken along the project execution;
- In the interim time the Senior Construction Manager, present in the Construction Home Office, will represent the Resident Site Manager in the new project since he worked at the Project during the Bidding phase;
- The designated new Resident Site Manager will receive, at Home Office care, all documents of the new Project to be studied.

[Figure 11.1 – Skidding of half ship and transport of new ship section for MSC Fincantieri Jumboization Project]

Another position that has to be covered as soon as possible is the Branch Manager. He is responsible for the implementation of the initial bureaucratic operations in the new country, having received the necessary power of attorney.

All this process becomes easier, if, in the Country where the Project has to be executed, a Company office is already in place.

The following step is to open a formal Site Office in the area. Resident Site Manager (or his substitute) has to visit the Client Representative and the site, including all the areas/facilities of interest for the new project (e.g. town, airport, harbour, roads, etc.).

Resident Site Manager first visit will be also used to establish a small group of site people in charge of preliminary operations.

This group is composed, among others, by a Civil Superintendent and the Camp Boss operating under the coordination of a Deputy Resident Site Manager.

Resident Site Manager (or his substitute) will visit site every month until his stable presence on site will be required.

From this time on, the Site Construction Organization can be considered completely structured although the number of its components will increase a lot.

Site Construction Organization has multiple relations inside the EPC Contractor Organization.

Project Management Organization is the natural hierarchic reference point. Construction Home Office, Discipline Engineering and Procurement Departments are important sources of information, tools and know-how as well, capable to address several questions originated, day by day, from Construction activities.

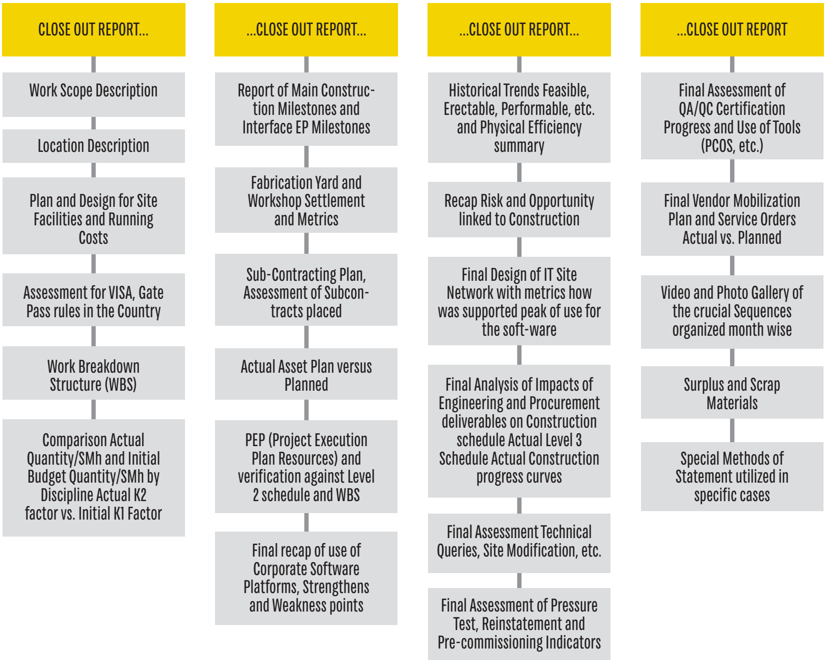
It is also important to mention the relation with the Branch office, crucial to assist Site operations.

All relations shall be established based on respect and cooperation, which are fundamental prerequisites for a successful project.

11.2 Construction Close-out Reports

It is crucial, along the Construction phase, as well as at end of the project, to capitalize the collected experiences.

The Project Manager is responsible for the preparation and distribution of the Close-out Report. The Resident Site Construction Manager cooperate as well (see Figure 11.2) consolidating the final project data, initially gathered as interim and then assessed along project life.



[Figure 11.2 - **Close out report]**

As mentioned before, close out reports related to previous similar projects (in terms of type of plant, area, size, client, subcontractors, etc.) can be of great help at the beginning of a new project promoting useful guidelines at both strategic and tactical level.

These reports play a relevant role in the project execution and they represent the real knowledge of the EPC Contractor, if correctly included and managed in the company database.

11.3 Constructability Lessons Learned

To correctly start the Constructability process (see chapter 7), it could be necessary to introduce in the EPC Contract Site organization the so called Constructability Coordinator, if Resident Site Construction Manager and Deputy Site Construction Manager cannot take care of this task.

This position can be taken on by one of the Senior Construction Engineers of the Construction Home Office. No other dedicated organizational positions are required.

Constructability Coordinator will cooperate with Engineering, Procurement and Construction Lead

Engineers in order to guide, monitor and check the overall construction process in terms of main phases best sequencing and different disciplines merging.

During Engineering and Procurement early phases, when Constructability has higher chance to be effective, he can work from Home Office. When Construction activities increases, if no one in the Site Organization can replace him, Constructability Coordinator will have to move on Site in order to better understand the real development of construction activities.

He will chair Constructability Meetings formed by the Lead Engineer of any discipline involved in the project.

[Figure 11.3 – Module transport for Comperji refinery Brazil (Fagioli)]

The Client Representative and even Construction Subcontractors, as soon as they are operative, are invited to attend these meetings to align all point of views of the involved stakeholders. The main target is to discuss concepts, processes and topics, listed in the recommended Lesson Learned (or check lists) available in both the EPC Contractor and the Client database.

New ideas and recommendations are welcomed and after a preliminary revision they shall be included in the items under revision, without losing the main milestone, deadlines and deliverable of the project.

Approved recommendations shall be implemented and closely monitored to control their effectiveness.

The importance of knowledge management is exhibited in the article "Assessment of CII Best Practices Usage in the Construction Industry" (S.B. Kim, 2014).

Along the overall project execution and especially approaching the final phase of the construction, it is important to verify positive and negative elements (events and technical decision) that characterized the construction phase(see Figure 11.4).

[Figure 11.4 - **Lessons Learned**]

12 | Construction activities along project life cycle

EPC Contractors scope of work usually includes Detail Engineering, Purchasing of all components and Construction up to completion (Mechanical Completion including Pre-commissioning or Commissioning and Start Up of the Units).

Construction Activities are present in all these processes, from the beginning of the bidding phase up to the end of the Contractual Obligations.

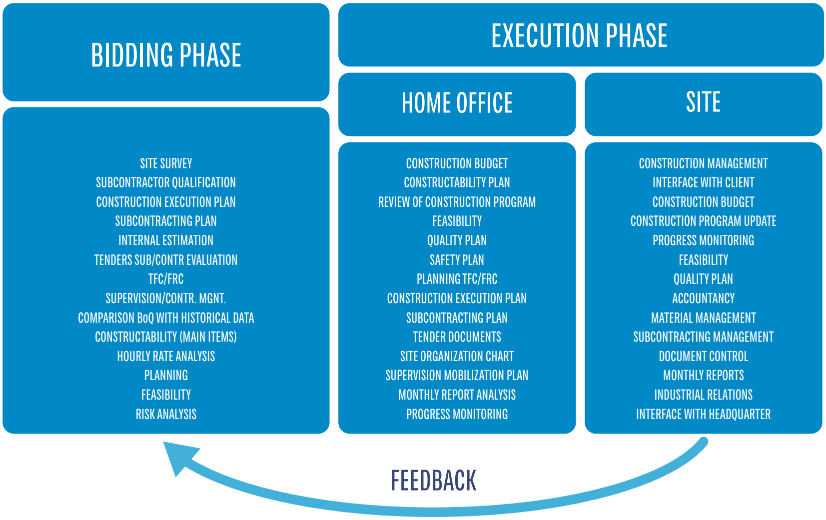
Construction Home Office is the first to be activated: it will guide and assist the Site Construction Team when it will become operative.

To give a more understandable view of the Construction engagement, all the activities, which have been described before, are concisely listed in the following paragraphs, separating Bidding, Execution and Commissioning Phases, Home Office and Site.

12.1 Construction involvement during project life-cycle

As shown in Figure 12.1, the Home Office Construction Department is involved in:

- Bidding phase;
- Execution phases - Home office and Site.



[Figure 12.1 – **Construction involvement of project phases]**

As previously stated (see Chapter 11), reporting feedbacks are fundamental to increase experience and feed the new project with revised and realistic data.

12.2 Bidding phase activities

Right after the bid/no bid decision (the EPC Contractors don't bid for all quotation requests coming from Clients), usually based on the backlog, management policies and financial resources, the Home Office Construction Department becomes active supporting the Proposal Manager in all matters concerning Construction.

Even though Home Office is the main theatre during the bidding phase, some activities have to be carried out before, on the Project Site area directly. Such activities are, in sequence:

- Site Survey enlarged to the area covering all parts involved in the Project;
- Subcontractors qualification assisting the proper Company Department in charge of this function;
- Subcontractors capability review starts on qualification data.
- Capability shall be focused on the need of the Project and on the preliminary Subcontractors Plan, which later on will be adjusted to real Subcontractors characteristics. An option to be con-

sidered in this phase is a partial Direct Hiring;

» Construction assessment in view of possible Joint Venture, Consortium or Nominated Subcontractors: if Company is considering these options, Construction aspects have to be deeply assessed. Partners Construction capabilities have to be checked through visits on their operative sites even if they are not in the Project area (as generally happen);

» Construction Execution Plan;

» Constructability studies have to be carried out with Engineering and Procurement Departments;

» Construction Plan is the most important product of Construction. It shall be harmonized inside the Project Plan; in this phase critical dates for equipment and deliverables have to be decided;

» Internal Estimate of Subcontractors/Direct Hiring parts, which are derived from Construction Plan;

» Supervision and Management Site Organization Chart and Plan (derived too from Construction Plan);

» List of 2 or 3 candidates to top positions in the Site Organization with proper Curriculum Vitae; usually this is a Client request but it is also a choice which have to be done by Construction Home Office;

» Temporary Construction Facilities and Accommodation Plans (commonly defined during the Site visit);

» After the definition of all main aspects related to Construction phase, it is necessary to produce a Construction cost estimation (to be included in the Company proposal). A Construction Risk Analysis has to be produced in view to Contingencies evaluation. In the estimate Supervision and Management Site Organization Costs and Field Running Costs have to be included;

» Home Office shall assist Procurement Department during negotiations assuring all know-hows requested in this phase and also evaluating all change options which are subject to consideration during bid assessment.

12.3 Project Execution Phase, Home Office activities

As soon as a Project has been acquired, with the Client contract signature (or with a letter of intent), Construction Home Office has to start the implementation of the necessary actions.

Site team has to be created giving that its assistance is one of the most important function of the Construction Home Office.

Other critical activities follow this sequence:

» Review Construction Plan introducing changes required by final contractual negotiations:

- Implement Construction portion of JV, Consortium agreement (if any);
- Review Nominated Subcontractors Plans (if any);
- Review Supervision and Management Organization Plan;
- Review TCF and Accommodation Plan;

» Review Construction Budget introducing changes required by final contractual negotiations with regard to the previous list;

» Nomination of Site Management top positions. These very important choices have to be done by the Head of Construction Department and endorsed by the Project Manager;

» Cooperation with HR defining candidates characteristics (internal and external) to cover all positions in the Site Organization Chart;

» Constructability activities have to be implemented in cooperation with Engineering and other Company Departments;

» Producing Construction Quality Plan;

» Producing HSE Plan;

» Assist Subcontracting Department in including in tender documents all necessary documentations and necessary information. This activity has to be done following sequence of Construction Works (First Civil Subcontracts then Transportation and Lifting, Mechanical, Electrical, instruments, etc.).

After receiving offers they have to be technically evaluated considering Site Management pieces of advice and in parallel with the assessment of Subcontracting Department.

This Subcontracting assignment operation will last several months;

- Assistance and support of Site Organization also sending Experts for limited time if needed and provide substitutions to Site Office people if necessary;
- Assist Site Organization in IT tools and software;
- Provide pieces of advice and documentation if requested.

[Figure 12.2 – Vessel transport in Marocco (Fagioli)]

12.4 Project Execution Phase, Site Organization activities

Site Office shall become fully operative in a few months. Organization chart and mobilization program constitute the guidelines for this process.

Top Positions goal is to transform a group of people, which possibly do not even know one other, in an efficient team.

The success of the Construction phase mainly depends upon the ability of the Site Supervision and Contractor Management Office to properly work for the project success.

Tasks of the Site in sequence are:

- Interface with Client, Client Consulting Representatives and other Authorities and external bodies;

- Cooperate with Branch Office;
- Implement and, if necessary, introduce changes to Accommodation and TCF Plan;
- Organize purchasing for office consumable materials;
- Organize sewer liquids, waste materials treatment and potable water treatment;
- Organize transportation from harbor, storage and distribution of materials arriving on Site. Issue of damage and missing reports;
- Organize in/out of Project documentation and subsequent distribution;
- Assist Subcontractors and Direct Hiring people to move in;
- Supervise and Manage Subcontractors operations;
- Assist and Supervise Heavy Transport and Lifting Operators;
- Continuous Progress calculation and organize weekly meetings with Client, Subcontractors and other parties having at the top of their agenda HSE matters;
- Issue regularly Reports and transmit them to all internal and external parties;
- Maintain daily contacts with Project Management and Home Office;
- Maintain proper Industrial Relations;
- Construction Plan update;
- Construction Budget update;
- Issue Progress Payments to Subcontractors;
- Organize external visits on Site;
- Organize sports and leisure time events for everybody involved in Project Execution;
- Organize assistance to Pre-commissioning, Commissioning and Start-up;
- Travel and living for Construction Team.

Reference

ANIMP. (2014). Advances in plant modularisation. ANIMP.

Anthopoulos, L. G., Kostavara, E., & Pantouvakis, J.-P. (2013). An Effective Disaster Recovery Model for Construction Projects. Procedia - Social and Behavioral Sciences , 74, 21-30.

Aven, T. (2011). On the new ISO guide on risk management terminology. Reliability Engineering and System Safety (96), 719-726.

Baxendale, T., & Jones, O. (2000). Construction design and management safety regulations in practice - progress on implementation. International Journal of Project Management (18), 33-40.

Chou, J.-S. (2011). Cost simulation in an item-based project involving construction engineering and management. International Journal of Project Management , 29 (6), 706-717.

Compass International Consultants Inc. (2013). Global Construction Cost and Reference Yearbook. Compass International Consultants Inc.

Concari, F. (2011). Constructability Methods and Tools. Impiantistica Italiana (2), 73-81.

Ferrè, L. (2013, April). Revamping of Control & Automation Systems. Industrial Plants , 105-110.

Griffith, A., & Sidwell, A. (1997). Development of constructability concepts, principles and practices. Engineering, Construction and Architectural Management , 4 (4), 295-310.

Hossain, M., & Chua, D. (2014). Overlapping design and construction activities and an optimization approach to minimize rework. International Journal of Project Management , 32 (6), 983-994.

Ibbs, W., & Vaughan, C. (2012). Change and the Loss of Productivity in Construction: A Field Guide.

Kim, S. (2014). Assessment of CII Best Practices Usage in the Construction Industry. KSCE Journal of Civil Engineering , 18 (5), 1228-1238.

Loiacono, O., & Botero, J. (2015). A Supporting Tool for the Rational Identification of Contracting Strategies for Complex Projects. Impiantistica Italiana (3), 47-56.

Manu, P., Ankrah, N., Proverbs, D., & Suresh, S. (2013). Mitigating the health and safety influence of subcontracting in construction: The approach of main contractors. International Journal of Project Management , 31 (7), 1017-1026.

Project Management Institute, Inc. (2014). A guide t the project management body of knowledge (PMBOK guide). Project Management Institute, Inc.

Shen, Y., & Walker, D. (2001). Integrating OHS, EMS and QM with constructability principles when construction planning - a design and construct project case study. TQM Magazine , 13 (4), 247-259.

Whittle, D. (2013, April). Transforming Diverse 3D Data into Focused Information. Industrial Plants , 125-127.

Wong, F. W., Lam, P. T., Chan, E. H., & Shen, L. (2007). A study of measures to improve constructability. International Journal of Quality & Reliability Management , 24 (6), 586-601.

Yang, J., Shen, G. Q., Ho, M., Drew, D. S., & Xue, X. (2011). Stakeholder management in construction: An empirical study to address research gaps in previous studies. International Journal of Project Management , 29 (7), 900-910.

Zhou, Y., Ding, L., Wang, X., Truijens, M., & Luo, H. (2015). Applicability of 4D modeling for resource allocation in mega liquefied natural gas plant construction. Automation in Construction , 50, 50-63.

POLITECNICO DI MILANO

Politecnico di Milano is a scientific-technological university which trains engineers, architects and industrial designers. The University has always focused on the quality and innovation of its teaching and research developing a fruitful relationship with business and productive world by means of experimental research and technological transfer.

Research has always been linked to didactics and is a priority commitment which has allowed Politecnico di Milano to achieve high quality results at an international level as to join the university to the business world.

Research activity moreover constitutes a parallel path to that formed by cooperation and alliances with the industrial system. The alliance with the industrial world, in many cases also favored by the Fondazione Politecnico and by Consortiums to which Politecnico belongs, allows the university to follow the vocation of the territories in which it operates and to be a stimulus for their development. The challenge which is being met today projects this tradition which is strongly rooted in the territory beyond the borders of the country, in a relationship which is developing first of all at the European level with the objective of contributing to the creation of a "single professional training market".

Politecnico takes part in several research and training projects collaborating with the most qualified European universities. Politecnico's contribution is increasingly being extended to other countries: from North America to Southeast Asia to Eastern Europe. Today the drive to internationalization sees Politecnico di Milano take part in the European and world network of leading technical universities and offers several exchange and double-degree programmes beside 2 three-year Bachelor of Science degree programmes, 10 Master of Science degree programmes, 12 Specialization Master's programmes and 24 Doctoral programmes which are entirely taught in English

www.polimi.it

ANIMP
ITALIAN NATIONAL ASSOCIATION OF INDUSTRIAL PLANT ENGINEERING

ANIMP is the Italian Association of Industrial Plant. Established in 1974, ANIMP is the "meeting centre" where Engineering Companies, Manufacturers of Plant Components and Universities may develop innovations and share common experiences to foster the construction of reliable and efficient industrial plants.

The joint goal of all members of ANIMP is to conceive and implement those improvements and changes that will enable them to respond quickly, with the right skills and technology to the challenges that world-wide Customers demand from industrial plants.

ANIMP Missions

- To represent and promote Italian plant industry (engineering, engineering and contracting companies, manufacturers of components for plants)
- To carry out events to increase the cultural and scientific knowledge, necessary for ANIMP Members to compete in the international market
- Indeed, through its Members, ANIMP is a highly qualified and prestigious vehicle of "Sistema Italia" in the world of the Plant Engineering & Supply Industry.
- ANIMP Members rely on the vast resource of more 95.000 highly skilled engineers and technicians.

www.animp.it

Board of ANIMP Construction Section

Mario Bernoni
Industrial Plant Business Development
Irem

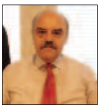
Paolo Cremonini
Director of Operations
Fagioli

Marco Di Gennaro
Support Services Section Head
Technip Italy

Gabriele Franco
Construction Director B.U. Oil & Gas
Rosetti Marino

Giordano Gariboldi
Project Control Manager EPD Division e Past Vice President IPMA Italy
Siirtec Nigi

Giorgio Giancane
Director of Operations Sices EC
Sices Group



Giuseppe Gioviale
Manager Construction Engineering
Tecnimont (Maire Tecnimont Group)

Mauro Mancini
Associate Professor, ANIMP Construction Section Coordinator
Dept of Management, Economics & Industrial Engineering - **Politecnico di Milano**

Michele Spongano
Business Unit E & C - VicePresident
Onshore Plant Construction & Fabrication - Department Manager - **Saipem**

Published by **ANIMP Servizi SRL** – Via E. Tazzoli, 6 – 20154 Milan – Italy
Edited by **Board of ANIMP Construction Section**
Executive editor: **Alberto Piana**
Graphic design: **Paolo Sicignano** (www.sicignano.net)
Print: **Tipografia Litografia A. Scotti Srl** – Via E. Berlinguer n. 6 – 20872 Cornate d'Adda (MB)

Source: cover photo by IREM

Companies involved