PROJECT TEAM

Frank-Peter Ritsche

PROJECT MANAGEMENT HANDBOOK FOR EPC

Plant Engineering, Procurement and Construction

First Edition – August 2014

www.project-team.org
ISBN 978-3-00-046425-6

CONTENT

1	**Introduction**	**1**
1.1	**The Project Life Cycle**	**2**
1.1.1	From Inquiry to Warranty	2
1.1.1.1	Acquisition Phase	3
1.1.1.2	Bid Phase	4
1.1.1.3	Project Phase	6
1.1.1.4	Warranty Phase	6
1.1.2	The PMI Life Cycle	6
1.1.2.1	Project Initiation	7
1.1.2.2	Project Planning	8
1.1.2.3	Project Execution	8
1.1.2.4	Project Control	8
1.1.2.5	Project Closure	9
1.1.3	The EPC Cycle	10
1.1.3.1	Project Management	10
1.1.3.2	Engineering	11
1.1.3.3	Procurement	11
1.1.3.4	Construction and Commissioning	12
1.2	**Application of Project Management Standards**	**14**
1.2.1	Project Management Standards	14
1.2.1.1	ISO 21500	14
1.2.1.2	IPMA®	15
1.2.1.3	BS 6079	15
1.2.1.4	PMI®	16
1.2.2	A translation into EPC's language	17
1.2.2.1	Integration	17
1.2.2.2	Scope	18
1.2.2.3	Time	18
1.2.2.4	Cost	18
1.2.2.5	Quality	19
1.2.2.6	Human Resources	19
1.2.2.7	Communication and Stakeholder	19
1.2.2.8	Risk	19
1.2.2.9	Procurement	19

2 Project Management 20

2.1 The Project Plan 20
2.1.1 Project Documentation Hierarchy 20
2.1.1.1 Project and Quality Plan - ISO 10006 and 10005 20
2.1.1.2 Content of the project plan 21
2.1.1.3 External and Internal Procedures 23
2.1.1.4 Project Planning Documents 23
2.1.2 Manual of Procedures 24
2.1.2.1 Project Manual 24
2.1.2.2 Design Manual 25
2.1.2.3 Site Manual 25

2.2 The Project Organization 26
2.2.1 Hierarchies of a Project Organization 26
2.2.1.1 External organization 26
2.2.1.2 Internal organization 27
2.2.1.3 Interface to executive management 28
2.2.1.4 A special case: project joint ventures 28
2.2.2 Roles and Responsibilities 30
2.2.2.1 Project Director 30
2.2.2.2 Site Manager 31
2.2.2.3 Project Management Functions 31
2.2.2.4 Support Functions 32
2.2.3 Integration Management 33
2.2.3.1 Definition of interfaces – scope sharing 33
2.2.3.2 Interfaces management inside and out of project boundaries 34
2.2.3.3 Reporting and decision making 34
2.2.3.4 Delegating responsibilities versus centralizing functions 35
2.2.3.5 Interface with the Home Organization 35
2.2.4 Human Resources 36
2.2.4.1 Staffing and Training 36
2.2.4.2 Human Resources Policies 37
2.2.5 Project Infrastructure 38

2.3 Project Structures 39
2.3.1 Work Breakdown Structures 39
2.3.1.1 WBS and Work-Package Definition 40
2.3.1.2 Work Assignment Process 41
2.3.2 Plant Breakdown Structures 42
2.3.3 Material Breakdown Structures 43
2.3.4 Other Structures 43

2.4 Communication Management 44
2.4.1 Hierarchies of Communication 44
2.4.2 Communication Plan 45
2.4.2.1 Correspondence 45
2.4.2.2 Meetings 46
2.4.2.3 Action Items Tracking 46
2.4.3 Crisis Management 47
2.4.4 Lessons Learned Process 48

2.5 Contract Management 50
2.5.1 Contracting: The Bid Phase 51
2.5.1.1 Bid and Contract Preparation 51
2.5.1.2 Bid and Contract Review 52
2.5.1.3 Assumptions, Clarifications, Exclusions 54
2.5.1.4 Legal and Commercial Aspects 54
2.5.2 Contract Management Set-up 56
2.5.2.1 Contract Management Organization 57
2.5.2.2 Contract Management Procedures 58
2.5.2.3 Contract Management Reviews and Training 60
2.5.3 Preventive and Active Claim Management 60
2.5.3.1 Claim Management Strategy 61
2.5.3.2 Scope and Cost Change Control 62
2.5.3.3 Schedule Change Control 64
2.5.3.4 Active Claims 64
2.5.3.5 Defensive Claims 66

2.6 Time & Resources Management 67
2.6.1 Scheduling Organization and Procedures 67
2.6.2 Schedule Development 68
2.6.2.1 Tools, Database Structures, Access Rights 71
2.6.2.2 Schedule Hierarchy 73
2.6.2.3 Schedule Structures and Filtering Criteria 73
2.6.2.4 EPC Sequencing 74
2.6.2.5 Interfaces with other Systems 75
2.6.3 Schedule Control 76
2.6.3.1 Baseline Schedule and Schedule Change Control 77
2.6.3.2 Schedule Update and Corrective Action 78
2.6.3.3 Progress Reports, Graphics and KPI's 79
2.6.4 Resource Planning 81
2.6.4.1 Skills and Organization 81
2.6.4.2 Quantitative and Qualitative Personnel Planning 82
2.6.4.3 Man Load Graphics 82
2.6.4.4 Resource Loaded Schedule 82
2.6.4.5 Other Resources 83

2.7 Cost Management **84**
2.7.1 Commercial Organization and Procedures 84
2.7.2 Cost Planning 84
2.7.2.1 Bid Phase Cost Estimation 85
2.7.2.2 Order Income Calculation 85
2.7.2.3 Payment Schedule and Cash-Flow Planning 86
2.7.3 Cost Control 87
2.7.3.1 Tracking of Actual Costs and Hours 87
2.7.3.2 Reporting Planned versus Actual Costs 88
2.7.3.3 Reporting POC, Earned Value 90
2.7.3.4 Invoicing 93
2.7.4 Business Administration 93
2.7.4.1 Finance: Loans, Interests, Hedging of foreign Currencies 93
2.7.4.2 Taxes, Customs, Fees 94
2.7.4.3 Bonds and Guarantees 94
2.7.4.4 Insurances 95
2.7.4.5 Legal compliance 96

2.8 Risk Management **97**
2.8.1 Risk Management Organization and Procedures 97
2.8.2 Risk Identification and Qualification 98
2.8.3 Risk Mitigation and Action Tracking 101

2.9 QHSE Management **103**
2.9.1 Quality Management 103
2.9.1.1 Quality Plan 104
2.9.1.2 Supplier Qualification 105
2.9.1.3 Inspections, Assessments, Audits 106
2.9.1.4 Non Conformance Control 108
2.9.2 Environment, Health and Safety 108

2.10 Progress Reporting **113**
2.10.1 Internal Reporting 113
2.10.1.1 Detailed Reporting 114
2.10.1.2 Project Management Reporting 117
2.10.1.3 Executive Reporting 120
2.10.2 External Reporting 121
2.10.3 The Reporting Cycle 122
2.10.3.1 A Monthly Reporting Time-Scale 122
2.10.3.2 Project Status Meetings 123

2.11 Document Management 124
2.11.1 Documentation Planning 124
2.11.1.1 Standard List of Technical Documents 124
2.11.1.2 Interface to Time Schedule 126
2.11.2 Documents Generation 127
2.11.2.1 Codification, Classification, Templates 127
2.11.2.2 Internal Workflows 127
2.11.2.3 Confidentiality 128
2.11.2.4 Archiving Requirements 128
2.11.2.5 Automatic Generation from Engineering Tools 128
2.11.2.6 Handling of Supplier Documents 129
2.11.3 Documents Workflow Control 129
2.11.3.1 Transmittal and Client Acceptance 130
2.11.3.2 Documents Tracking 131
2.11.4 Configuration Management for Documents 131
2.11.4.1 Lifecycle and Revision Control 132
2.11.4.2 Rendition Management 132
2.11.4.3 Composition of Virtual Documents 133

2.12 Information Management 134
2.12.1 Project specific IT-Architecture 134
2.12.1.1 Project Management Tools 135
2.12.1.2 Design Integration Tools 136
2.12.1.3 Engineering Tools 137
2.12.2 Communication Platforms 137
2.12.2.1 Project Drives 137
2.12.2.2 Web-Portals, Sec ure Extranet Services 138
2.12.3 Data Security 139

3 Engineering 140

3.1 Engineering Process & Procedures 140
3.1.1 The Engineering Disciplines 141
3.1.1.1 Systems Engineering 141
3.1.1.2 Mechanical Engineering 144
3.1.1.3 Plant Layout and Civil Engineering 144
3.1.1.4 Electrical, Instrumentation and Controls, HVAC 146
3.1.2 Engineering IT 148
3.1.2.1 P&ID's and Engineering Database 149
3.1.2.2 3D Plant Layout 149
3.1.3 Improving Engineering Efficiency 150
3.1.3.1 Modularization and Engineering Re-Use 150
3.1.3.2 Cost Engineering 151

3.2 Technical Configuration Management 153
3.2.1 Configuration Management Plan 153
3.2.1.1 ISO 10007 Requirements 153
3.2.1.2 Definition of Configuration Management in EPC Projects 154
3.2.2 Technical Change Management 155
3.2.2.1 Design Reviews and Design Freezes 156
3.2.2.2 Technical Change Notices 157
3.2.2.3 Data Status Tracking, Data Revisioning 157
3.2.3 Data Exchange/ Data Life Cycle 158
3.2.3.1 Data Lifecycle Requirements for O&M 158
3.2.3.2 Data Handover to Owner/ Operator 159
3.2.3.3 Standardization of Data Exchange 160

3.3 Licensing Management 161
3.3.1 Requirements Management 161
3.3.1.1 Codes, Standards, Regulations 161
3.3.1.2 Requirements Management Process 162
3.3.2 Licensing Plan 163
3.3.2.1 Construction License 164
3.3.2.2 Operation License 164

4 Procurement 166

4.1 Procurement Process & Procedures 166
4.2 Material Take-Off 168
4.2.1 Material Catalogue 168
4.2.2 Generation of BoM 169

4.3 Procurement Planning 170
4.3.1 Solicitation 170
4.3.2 Supplier Selection 171
4.3.3 Supplier Contracts 173

4.4 Procurement Control 174
4.4.1 Purchase Order Tracking 174
4.4.2 Manufacturing and Inspections 175
4.4.3 Transportation and Export 176

4.5 Stocks 178
4.5.1 Material Reception on Site 178
4.5.2 Site Warehouse Management 178
4.5.3 Interface to Financial Asset Management 179

5 Construction and Commissioning 180

5.1 Site Management Organization and Procedures 180

5.1.1 Site Organization 180
5.1.2 Site Procedures & Instructions 181
5.1.3 Aspects of International Construction Sites 184
5.1.3.1 Legal status and registration obligations 184
5.1.3.2 Taxes 185
5.1.3.3 Human Resources 186

5.2 Construction Planning 188

5.2.1 Site Infrastructure and Logistics 188
5.2.1.1 Site layout and permanent facilities 189
5.2.1.2 Site infrastructure and temporary facilities 189
5.2.1.3 Scaffolding and weather protection 190
5.2.1.4 Horizontal and vertical transports 191
5.2.2 Construction processes 192
5.2.2.1 Civil construction 192
5.2.2.2 Mechanical erection 193
5.2.2.3 Electrical and I&C installations 196

5.3 Construction Execution and Control 197

5.3.1 Site Coordination and Interface Management 197
5.3.1.1 Word Order System 197
5.3.1.2 Subcontractor Management 198
5.3.1.3 Field Engineering 198
5.3.2 Inspection and Supervision 199
5.3.2.1 Inspection Planning and Interface to Engineering 199
5.3.2.2 Organization and Coordination of Inspections 200
5.3.2.3 NDE and Baseline ISI 201

5.4 Commissioning 202

5.4.1 Mechanical Completion Management 202
5.4.2 Commissioning Program 204
5.4.2.1 Commissioning documentation 204
5.4.2.2 Commissioning process 205
5.4.3 Handover to Owner/ Operator 205

1 Introduction

Foreword

Excellence in project management is a key success factor in doing business across all industries. New innovations in finance, in IT, in the health sector are managed as projects. The developments of new products in automotive, aerospace, shipbuilding, in any producing sector are managed as projects. The planning and construction works of new buildings, infrastructure or industrial plants are managed as projects. Although the characteristics of such projects differ significantly there are basic principles that apply to all different kind of projects.

A couple of good project management standards have developed around the globe, but I consider the Project Management Book of Knowledge (PMBoK®) of the US based Project Management Institute (PMI®) the most accurate and internationally recognized standard in the world. The PMBoK® knowledge areas can be correlated with the ISO 21500 standard (Guidance on Project Management) that was edited in 2012 and is aimed to describe common sense among the various project management standards, organizations and industries. These standards and associated guidelines have evolved during the last years to a maturity that they can be applied to any project, no matter what size, no matter the nature of business. And exactly that universality is the challenge we face in the EPC business.

The construction projects of large industrial plants are among the most complex projects. Construction companies who cover the engineering, procurement, construction and commissioning of industrial plants are called EPC contractors. I have been working in EPC projects since more than 20 years, in project management and engineering offices, in manufacturing facilities and on construction sites, in projects from some hundred thousand Euros up to several billion Euros. I always was missing a guideline that translates the common project management standards into the complex and specific world of the EPC business. This is the reason why I wrote this handbook.

The food served in this book is probably something heavy to digest for a project management beginner. The knowledge of project management standards such as the PMBoK® will definitely help to fully benefit from the lecture of this book and to apply it adequately to your own organization. On the other hand – some of the tools and methods described here may only be reasonable for really complex mega-projects. Don't crack a smaller nut with a sledgehammer.

If you are a contractor in an EPC project, the owner or operator of a process plant or a developer of project management software or engineering tools: I wish this handbook will give you some practical ideas how to improve your project. And I would like to invite you to share your remarks with me to make this handbook even better.

Düsseldorf, August 2014
Frank-Peter Ritsche

2.2 Project Organization

For complex EPC projects the project organization is more than a project manager and his team. Standards like the PMBoK® address the project organization as a human resources issue. This is definitely correct and needs to be addressed here, but it's more than that. With the project organization we assign responsibilities to the individual shares of scope. With the project organization we define the interfaces between the different members of this organization, and these organizational interfaces can be the key to success - or failure of the project. With the project organization we also need to set up the infrastructure, e.g. the arrangement of offices for the team. This Section will provide an overview of what needs to be considered for setting up the project organization, and how this could be written down in a project organization procedure.

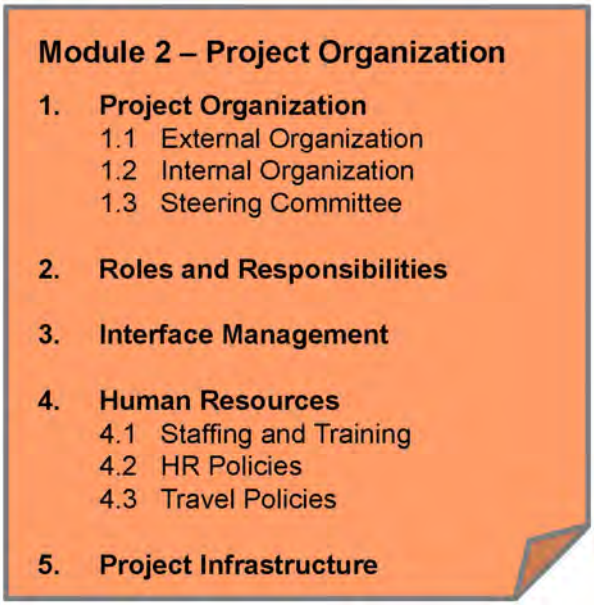

Figure 2-6

2.2.1 Hierarchies of a Project Organization

There are a thousand-and-one ways to organize a project. There are aspects like the availability, capability, efficiency of resources, the minimization of interfaces or corporate business strategies that determine the structure of an organization. There are strong hierarchical organization forms, there are matrix organization forms. There is a permanent home organization where the temporary project organization must fit into. What-ever the final project organization will look like: There is always an external and an internal project organization hierarchy that follows some basic principles. And: the project manager must be aware that he has to ensure the management of all the interfaces within this organization.

2.2.1.1 External organization

The external project organization of an EPC project defines the high-level relationships between the different companies involved in the project. From the perspective of the EPC or main contractor(s) in charge to engineer, procure and build the plant, there are typically two or more levels of subcontractors and their sub-suppliers that need to be managed. An organization chart of the external project organization will only show the most important ones, since generally subcontractors and sub-suppliers will be managed through the procurement organization. If the EPC or main contractor is not just one company, but a project joint venture (consortium) of two or more companies, this needs to be reflected in the organization chart of the external project organization.

Above all that is the client as the top-level of the external organization, but there could be further organizations that interface with the EPC (or client/ owner/ operator) on a high level, e.g. licensing authorities or an architect engineer. The following figure shall illustrate an example.

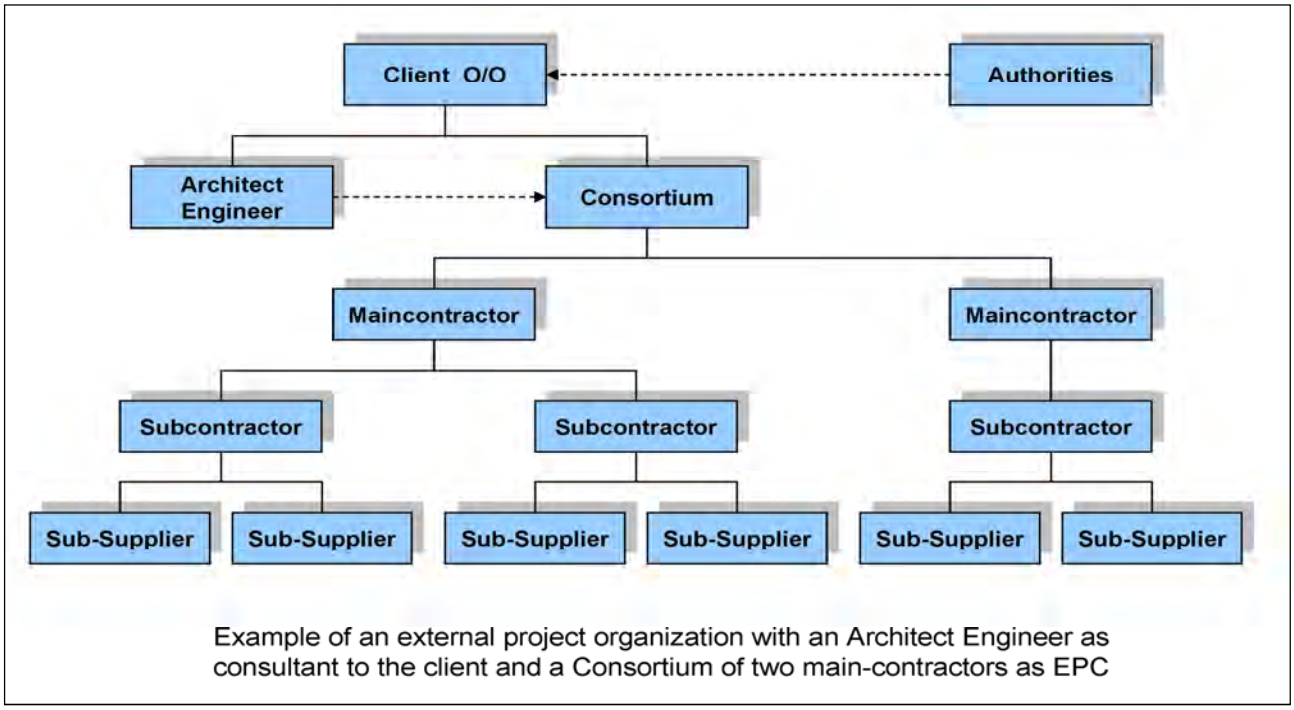

Figure 2-7

The external organization is the basis for many contractual relations in the project. Each link between two boxes in this chart reflects a contract between two parties. Each link reflects an interface that needs to be managed, and for which a set of procedures should be in place, how the two parties shall work together. Section 2.1.1.3 has already elaborated on these procedures. For each of the parties in the organization the share of scope must be dearly defined: without overlap, and without gap. The "responsibility assignment matrix" is a tool to assign the work-packages of the work-breakdown structure (WBS) to the organization - It will be described further below In Section 2.3.1.2.

2.2.1.2 Internal organization

The organizational set-up of the project team within one of these boxes of the external organization is the internal organization. Where the internal organization of a small project may simply consist of the project manager and his team, there will be a more complex organizational hierarchy in a large EPC project.

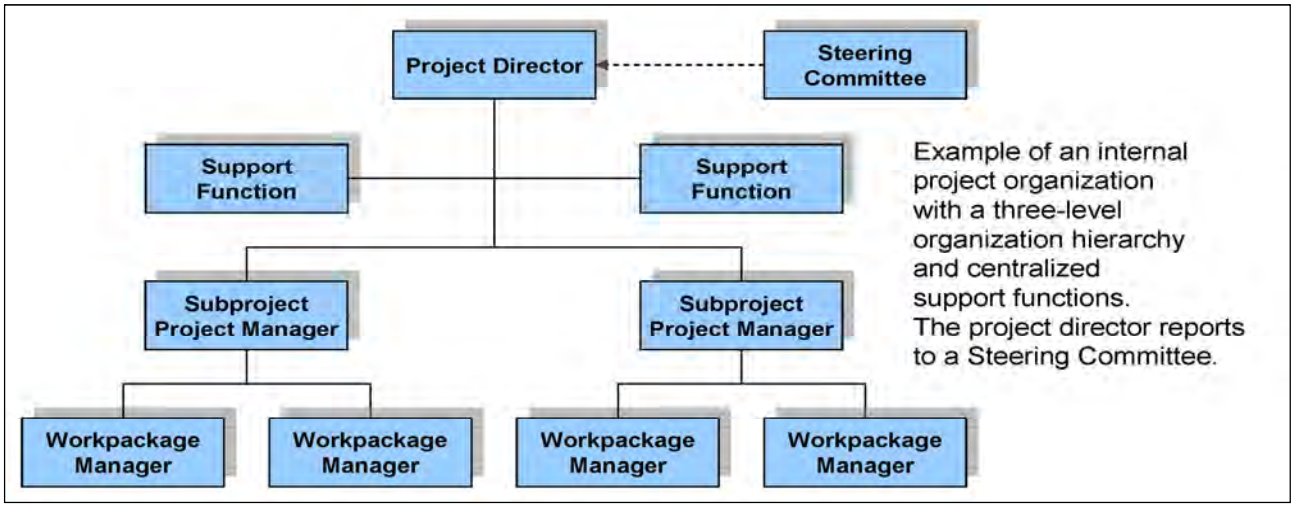

Figure 2-8

Section 2.3 of this handbook will deal with the work-breakdown-structure (WBS) of a project, but one rule should be already mentioned here: the organization structure and the WBS are two different things. However there should be one principle respected when defining the WBS and when defining the project organization: On the lowest level of both structures, it must be possible to assign one single organizational responsibility to *one* or more work-packages of the WBS. This is why the lowest level of the project organization chart should be the manager of a work-package. He has the full responsibility for planning, executing and controlling the scope of his work-package, and he functions as a project manager for his small share of the project. He leads a small team, and he follows the instructions given by the next higher management level of the project organization, where he also reports to.

This intermediate level I have named the subproject-level. There could be more intermediate levels in a project organization, but their function generally is the same: The project manager of a subproject is the interface manager of the work-packages that belong to his subproject. His main role is integration management, and he has to consolidate the reports of his work-package managers on the subproject-level. At the same time he is reporting bottom-up to the next-higher level.

The highest level in a complex project organization is the project director. He is the leader of the overall project, and as he has broken down the overall project into a manageable number of subprojects, the project managers of these subprojects report to him. Again, the project director is the interface manager of the subprojects.

In addition the project director will support the project organization with some centralized support functions. Typically the commercial project manager, time scheduling manager, quality manager or possibly a central project documentation office are such support functions. They will be described further below in Section 2.2.2.

2.2.1.3 Interface to executive management

The project director has the authority to take all decisions within the boundaries of his project. He is empowered by executive management through a project charter or a letter of delegation to execute the project with the involvement of the corresponding organization units of the home organization and external organizations.

For a large project with several external organizations involved, it is common practice to establish a steering committee, which represents the executive management of the involved organizations. The project director will report to this executive steering committee that acts as the ultimate decision level for issues or conflicts that cannot be solved within the project directors' responsibility. If there are decisions required that are outside the limits of the project, the project director shall present to the steering committee, which is responsible to drive the decision to the appropriate level. The project director is responsible to prepare such decisions with all supporting facts, such that the steering committee is able to decide.

For the project director it is important to fix the principles of cooperation between his project and the steering committee in an organizational paper (e.g. the reporting lines, periodicity of board meetings, members of the committee), and to obtain a signed commitment on these principles. This agreement should be part of the project plan.

2.2.1.4 A special case: project joint ventures

In large construction projects two or more companies may join their forces in a project joint venture or consortium. They will split the total scope among the consortium partners and define their rules of cooperation in a consortium contract. In front of the customer the consortium may act as one face (closed consortium), or may maintain direct relations between the individual partners and the client (open consortium). The consortium contract will also define a consortium leader and the specific rights and duties of this leadership role.

The responsibilities of the project director of a consortium are different to those of the project

2.3 Project Structures

There're various structures in one project, not just one. The work-breakdown-structure (WBS) certainly is the most important one, as it should break down the work scope in a logical manner reflecting by definition 100% of the work scope, without overlaps, without gaps. It is one important coding element that will be used for the coding of costs, for the coding of scheduled activities or for the coding of documents. But: it is not the only one.

The organization structure is another structure in the project, and in the following Section it'll be explained, why organization structure and WBS are two different things. There're coding structures for the final product: the process plant. There're coding structures for the material that'll be procured. There're coding structures for documents, account structures for the costs. Codes for a variety of criteria are assigned to the time schedule activities that allow filtering and sorting to those criteria.

These structures all have one thing in common: They need to be defined at the start of the project, and changing a structure or introducing another structure at a later stage of the project is either impossible or extremely costly. The project plan should dedicate one module to these definitions, which may follow the structure of this Section, but most of the definitions should even be fixed before contract signature.

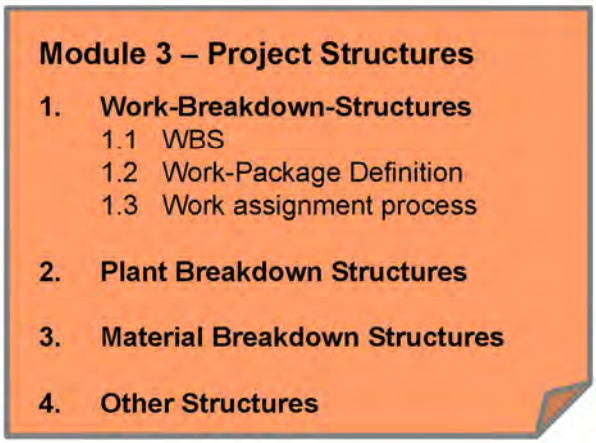

Figure 2-15

2.3.1 Work Breakdown Structures

The work-packages are the lowest level of a WBS, and the WBS shall arrange these work-packages in a hierarchical and logical structure. Each work-package shall be clearly described by its scope, but also by clear responsibility, clear budget, clear scheduled dates to the scope of each of these work-packages. The consequence is: the WBS shall allow an easy mapping to the organization structure, costs breakdown, schedule breakdown. And this is the way the WBS should be used in the project: It is the element that ties together all the elements in project space; the scope, the costs, the time, the people, the documents, the risks...

Important is the deliverable orientation of the WBS, since beside all other coding structures in the project, the WBS is the one that describes the scope. Any deliverable in the project that cannot be clearly assigned to a work-package is not part of the project!

Work Breakdown Structure (WBS)

Definition of PMBoK®: The WBS is a deliverable-oriented hierarchical decomposition of work to be executed by the project team to accomplish the project objectives and create the required deliverables. It organizes and defines the total scope of the project. Each descending level represents an increasingly detailed definition of the project work. The WBS is decomposed into work packages. The deliverable orientation of the hierarchy includes both internal and external deliverables.

Work Breakdown Structure (WBS)

Definition of PMI® Practice Standard for WBS, 2001: The WBS

- ⇨ decomposes (or disassembles) the overall project scope into deliverables and supports the definition of the work effort required for effective management.
- ⇨ clearly and comprehensively defines the scope of the project in terms of deliverables that the project participants and stakeholders can understand.
- ⇨ supports documenting the accountability and responsibility for the various deliverables by having a direct relationship between the WBS elements related to the Organizational Breakdown Structure (OBS) identified through the Responsibility Assignment Matrix (RAM).

2.3.1.1 WBS and Work-Package Definition

Defining the WBS is a work that includes two activities:

(1) Defining the content of the work-packages and
(2) Defining of the hierarchical structure, how these work-packages are assembled in a logical order.

Both activities are performed in parallel, but generally it is the first step to think about the criteria that will structure the scope.

There're many ways to give a structure to the same project, and there may be good reasons to choose one or the other structuring criterion as a superior or lower level criterion.

Such structuring criteria are e.g.:

- by contract: e.g. scope of company A, scope of company B
- by plant: e.g. building 1 of the plant, building 2 of the plant
- by time phase: e.g. engineering phase, procurement phase, construction phase
- by discipline: e.g. civil works, mechanical scope, electrical, instrumentation & controls

The following graphics show examples, how the WBS can be arranged using these criteria. It is the project manager's challenge to select the model that will fit best to the specific characteristics of his project.

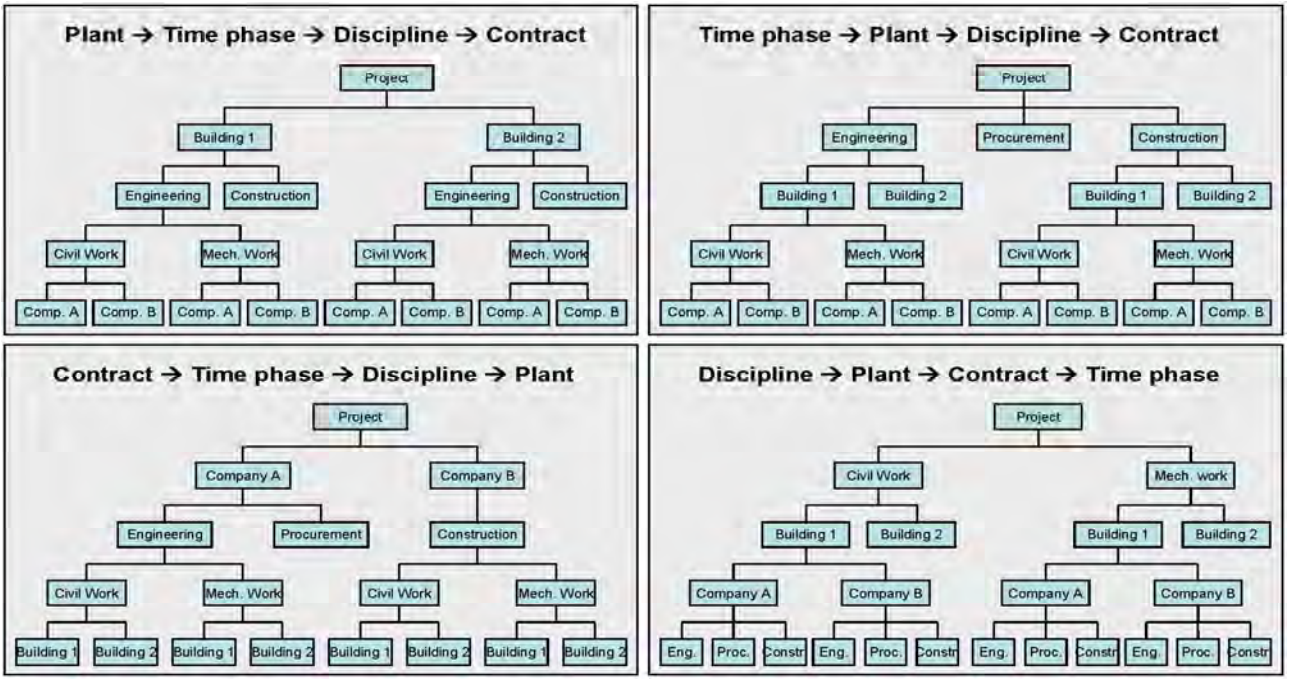

Figure 2-16

Many companies try to standardize the WBS for the projects they execute. There're some huge advantages in using the synergies from one project to another:

(1) Facilitating bid calculations and speeding up tender preparation: In most cases the only way to generate complex offers is to reuse the WBS of a similar project to meet the challenging deadlines of the tendering process;

(2) Re-use of design packages and documentation from previous projects;

(3) Channelling the flow of lessons-learned from one project to the next.

Using a standard WBS may be a compromise, especially if a project specific WBS may better fit with the controlling needs of the project. Again it is the project manager's duty to balance between the pro's and con's of a standard WBS versus a project specific WBS. In some cases there may be good reasons to use two WBS in the same project.

Defining the structure is one step, defining the content of the work-packages is another step. There's no rule, what comes first. Sometimes, when the scope is well defined, it's relatively easy to describe the content of the work-packages, but long discussions are spent to agree on the best way to arrange them in a structure. Sometimes, the structure is obvious, but a lot of work is needed until the scope of each work-package has been developed to the necessary level of detail.

The content of a work-package is described in a work-package description or a WBS dictionary, which should contain the information shown below.

Work-Package Description

- ☒ WP-Number
- ☒ WP-title
- ☒ Responsible person
- ☒ Costs (budget/ budget breakdown)
- ☒ Time (milestones, time schedule)
- ☒ Description of deliverables (documents, design, material, installations ...)
- ☒ Description of input required
- ☒ Description of interfaces
- ☒ Description of contractual basis (contract documents, procedures, codes & standards, quality requirements)
- ☒ Resources (man-power, equipment)

Figure 2-17

2.3.1.2 Work Assignment Process

I need to stress it again: a WBS is not an organization structure. This is often being confused, because certainly it'll be ideal, if the WBS will follow the reporting lines of an organization. But: the organization may be changed or adjusted, as to the needs of a project. The WBS should not be changed! And a standard WBS that'll be adjusted with organizational changes is no standard WBS.

However there's one guiding principle that is valid for both the WBS and the organization structure: at least on the lowest level of both structures, the two structures should allow a direct mapping, which means clear assignment of one organization unit to one work-package must be possible. The tool to do this mapping is the "Responsibility Assignment Matrix" (RAM). A scope split in the contract is nothing else than a high-level RAM.

One word to the organizational breakdown structure (OBS) that should be used in the responsibility assignment: There will be work-packages that will be assigned to technical departments of the corporate home organization or work-packages that will be assigned to subcontractors. It is the project specific project organization that reflects this fact, not the corporate home organization. Especially in large projects with a high content of subcontracting the responsibility assignment will develop with the supplier negotiations - another reason, why the WBS should not focus too much on the OBS.

Each work assignment to an external company establishes a contractual relationship. This is the reason why the work-package description should be as precise as possible. If large packages are subcontracted, the WBS requirements should be negotiated with the supplier, otherwise the reintegration of the subcontracted scope into the

2.7 Cost Management

At the very end, it's all about money. Unplanned scope, schedule delays, poor quality, whatever issue jeopardizes the plan – it all translates into cost changes and budget overruns, shrinking margins or even losses. And no project manager will gain his bonus payment, when he completed the project within or even before schedule, but overrun his budget. Even if in larger projects commercial managers will take care for the cost accounting and reporting in a project, neither cost planning nor cost control is something that the project director can delegate. The ultimate project goal for an EPC contractor is to earn money.

2.7.1 Commercial Organization and Procedures

The responsibility of the commercial organization goes beyond cost management. Cost management in a project is cost planning and cost control, including the accounting of costs (Cash-Out) and the invoicing (Cash-In). Commercial management however also includes all the business administration, such as finance, tax, insurance or legal issues, and the project director has to ensure that these functions are covered by the organization, no matter whether it's the corporate organization or his project organization that is in the lead. The following sections shall not be aimed to educate commercial managers, but the (technical) project manager shall be sensible for the commercial and administration issues up to a level of detail where he's confident that nothing falls between the gaps.

The cost management plan shall cover the areas headlined in Figure 2-50 and further described here below. The commercial organization could be as easy as a simple list of responsibilities, a list of commercial management functions with an assignment of corporate departments in charge. The commercial organization however can be more complex, especially when the project is managed in a consortium set-up.

Cost management in a consortium generally is the duty of each consortium Partner, however there're areas, where the consortium leader may take the lead or interact with the partners, such as invoicing or the management of bonds.

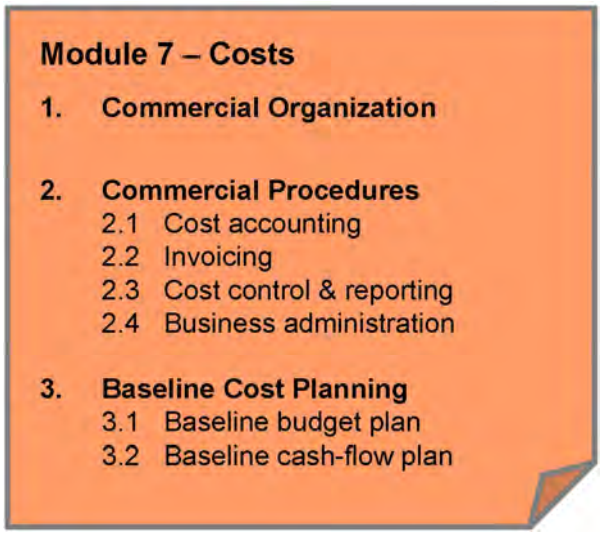

Figure 2-50

2.7.2 Cost Planning

Cost planning happens along these dimensions: Money and time. It considers not only the Cash-Out (time-phased budget), but also the Cash-In (payment schedule), see Figure 2-51.

While the cost estimation during the bid phase may not go down to the lowest level of detail, it is necessary to develop the detailed budget baseline upon contract award in order to perform an effective cost control during the project execution.

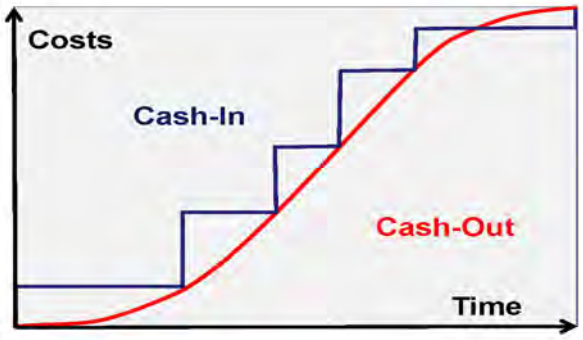

Figure 2-51

2.7.2.1 Bid Phase Cost Estimation

The work-breakdown-structure (WBS) provides the framework for assembling the budget out of hundreds, later during project execution sometimes several thousands of individual cost elements. As explained in Section 2.3.1.1., a work-package shall be defined by its scope, schedule and budget, however the level within the WBS, where a budget is assigned, may not always be the lowest level. Especially during the bid phase cost estimates may be assigned on higher levels of the WBS, based on experience or based on scaling up or down historical data from previous projects.

There're different methods to estimate the costs of work, and both bottom-up as well as top-down methods can be used. Projects that are estimated bottom-up have the tendency to be too conservative and thus too expensive to compete on the market, while projects that are calculated top-down (e.g. based on market price) may end-up in lack of commitment about the distribution of the available budget. As always, the best compromise is somewhere in between.

The cost estimation of a project generally consists of these main elements:

- Direct costs, that are the costs that can be directly assigned to scope delivered or work performed for the project.
- Indirect costs, that are overhead and other (corporate) costs. Such costs are often added as a percentage on top of the project costs, and often the project manager has little influence on these cost positions.
- Contingency reserves that may be included to consider risks. Such costs may be added on top as a management reserve, and/ or on various levels within the direct costs. Wherever contingencies are considered in the cost estimation, they shall be considered only once for the same risk.
- Margin, most important, that transforms costs into a price. And then translates for the financial controllers into EBITDA (earnings before interest, taxes, depreciation and amortization), EBIT (earnings before interest and taxes), EBT (earnings before taxes) and EAT (earnings after taxes).

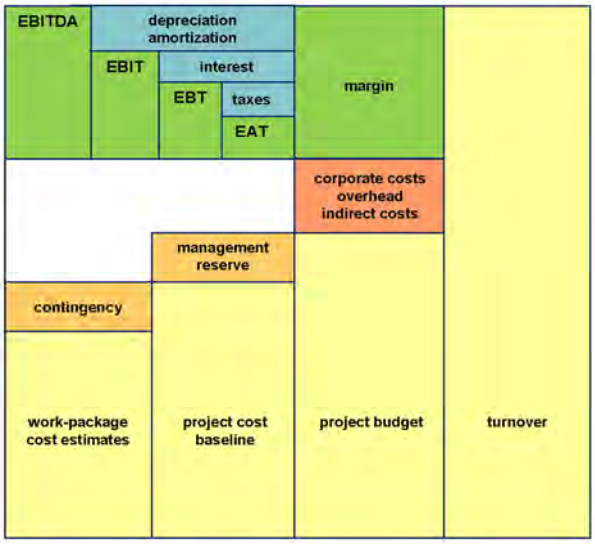

Figure 2-52

Cost planning during the bid phase is not complete for large projects with large budgets without time-phasing the budget and developing a payment schedule, which is mandatory to forecast the cash-flow during the project duration and derive eventual financing needs.

2.7.2.2 Order Income Calculation

The order is in the books, and the SAP system has to be configured such that all project costs can be assigned to the cost accounts and cost categories and cost centers on a detailed level that enables effective cost control. Effective control does not mean, that breaking down the costs into microscopic cost accounts increases the control over the project. While in some areas of the WBS it may be necessary to split the budget within one work-package into several smaller cost-accounts, it could be more appropriate in another area to assign the budget on a higher level of the WBS, may-be simply because a larger portion of the WBS will be subcontracted as a fixed-price package.

Costs generally will be assigned to at least three different structures:

- Cost object (that is the cost account within the work-breakdown-structure)
- Cost categories, e.g. by cost elements (such as labour costs, material costs, indirect expenses) or by behaviour (such as fixed costs, variable costs)
- Cost center (who within the organization will collect these costs)

Cost categories and cost centers shall be defined in a standardized way within corporate ERP systems such as SAP, so the project manager shall not worry about these structures, however the definition of the cost accounts based on the WBS is project specific, unless a standardized WBS has been developed, see 2.3.1.1.

Within the cost categories of an EPC project, the treatment of costs and costs collection will differ, and the ERP systems generally provide a variety of different routines and reports tailored to these cost categories:

- Direct labour costs, e.g. for engineering-hours or working-hours on site are in most cases collected as hours in (electronic) time-sheets, and then within the ERP system transformed into costs as a product of quantities and hourly rates. Cost control in this area may rather be performed as controlling of hours.
- Subcontracted labour (if permitted by national law) may-be managed as costs or as hours; this depends on whether where the time is registered.
- Subcontracted services will be managed as costs; Section 4.3.3 will discuss the different payment models, such as unit price or fixed price.
- Material supplies will be managed as costs, no matter whether ordered as raw material or assembled components. Procurement is in charge for these costs. The same is valid for other expenses, such as rental of equipment, logistics, machine costs, consumables etc.

The order income calculation shall reconfirm the budgets determined in the bid phase cost estimation. At the same time the work assignment process is started, and the responsible organization units will be requested to commit to the planned budgets. The same is valid for main portions that are subcontracted, and as this involves negotiations, there will be requests to adjust the budgets. The project manager shall fix his baseline budget plan very soon after contract award, otherwise no effective cost control is possible. Negotiation results, be they positive or negative, will better be traced within cost control and cost change management, otherwise the baseline budget plan will not be completed before the project ends. What was said about the baseline schedule is valid for the baseline budget too: A plan that just documents history is worth nothing.

2.7.2.3 Payment Schedule and Cash-Flow Planning

The project objective is not to spend money, but to get money. So we shall spend the same effort to collect our payments as we plan and control our costs. I've seen engineering companies taking in huge orders, that had to file for bankruptcy simply because their banks were not willing to finance huge depths any longer that were due to negative cash-flow. Cash-flow orientation is an attitude that has not yet entered everywhere into project management behaviour – in fact cash-flow-planning is not an element of recognized project management standards such as the PMBoK®.

Cash-flow is the difference between "Cash-In" (client payments) and "Cash-Out" (payments to personnel, subcontractors or suppliers), see Figure 2.51. When the cash flow is positive at a given time, we have money at the bank and may earn some interest for that, as we have to pay interest for loans in case we have to finance a negative cash-flow. Whenever we need loans to finance our depths, it is wise to negotiate conditions and limits with the bank before, otherwise… see above paragraph. We most naturally do that whenever we finance a private car or purchase a house, so why don't we care about this aspect when we finance our project?

The cash-flow depends on the "Cash-In" side on the payment schedule that has been negotiated with the client. At best (for the EPC) the client will pay an advance payment, before money is spent, latest at contract award. In large EPC-contracts the total amount of the price is split into a series of payments, when a defined amount is paid, once a defined milestone in the project has been achieved. This payment schedule is not directly the "Cash-In", as what the contract defines as "payment milestone" normally constitutes the date, when the invoice with

2.12 Information Management

Nothing has changed so dramatically the way of our daily work during the last 20 years as the progress in Information Technology (IT). In theory, there shall always be the business processes in the lead who define our working methods, and IT-software shall just support and follow the business processes. But progress in IT is often one step ahead of our working culture, and the opportunities of powerful IT-software more and more takes over the command over our business processes. So in today's reality it is often the business processes that follow the lead of IT.

This handbook is about business processes in project management, engineering, procurement and construction. It is unavoidable to address the implementation of such processes in today's information environment. A project manager or project director cannot ignore the impact of IT and it is mandatory for him to develop an understanding of the risks and opportunities of information management. It is an integral part of integration management, the core function of a project manager that he cannot simply delegate to an IT-department.

2.12.1 Project specific IT-Architecture

Project specific IT-architecture? We are a modern state-of-the-art company, we have an IT-department with an IT-policy, we have defined IT-tools and software within our organization that has been configured to fit our business processes. We will not invent new project-specific IT-solutions just because we win another big contract! True? Yes, it's true, as long as our view is focussed on the scope of work that is performed directly within our own organization.

But a project horizon of a project director shall go beyond the own scope. The external project organization includes the client, eventually consortium partners, main contractors, subcontractors and suppliers, all professional modern state-of-the-art companies… who have an IT-department with an IT-policy, who have defined IT-tools and software within their organization that has been configured to fit their business processes.

Our daily work in the project is the exchange of information, of documents, of electronic data. Within the boundaries of our own organization, and across these boundaries with our external business partners. The way how we exchange this information most efficiently is project specific, since our business partners are different from each project to the next. Efficient information exchange is more than sending and receiving emails. It must consider the opportunities of data exchange between our own IT-tools and the tools that are implemented with our partner's organizations.

The IT-organization within the project organization shall be managed by IT-experts from a corporate IT-department. It is not the job of a project to administer and maintain IT-systems. For a large project however an own IT-expert within the project organization may pay off, who'll be in charge to define the project requirements regarding IT to the corporate department and supervises the efficiency of information management. And in doubt it is the project manager himself or a project logistic manager who has to discuss information management concepts with the IT experts and seek their advice and support.

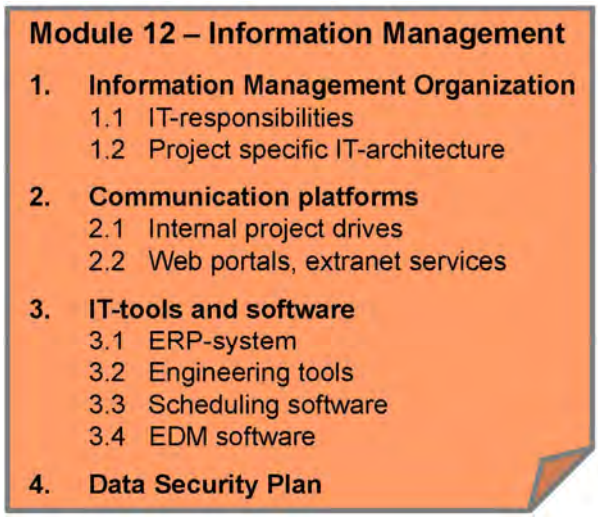

Figure 2-85

An information management plan as an essential element of a project plan? Yes! It'll be negligent to miss that point in an EPC project. Figure 2-85 suggest a structure for such a plan, and even if not all areas may-be relevant for less complex projects – issues such as data security are too important to miss in any project.

The IT-architecture in a typical large EPC project comprises the project management tools, design integration tools and the specific engineering software, see Figure 2-86. The software applications for the various tasks have evolved from previously stand-alone-tools to more and more integrated networks, where at least the market leaders are able to interface each other. “Data warehousing”, or “Business Intelligence” provide further concepts to integrate data from different IT-systems, specifically when it comes to reporting.

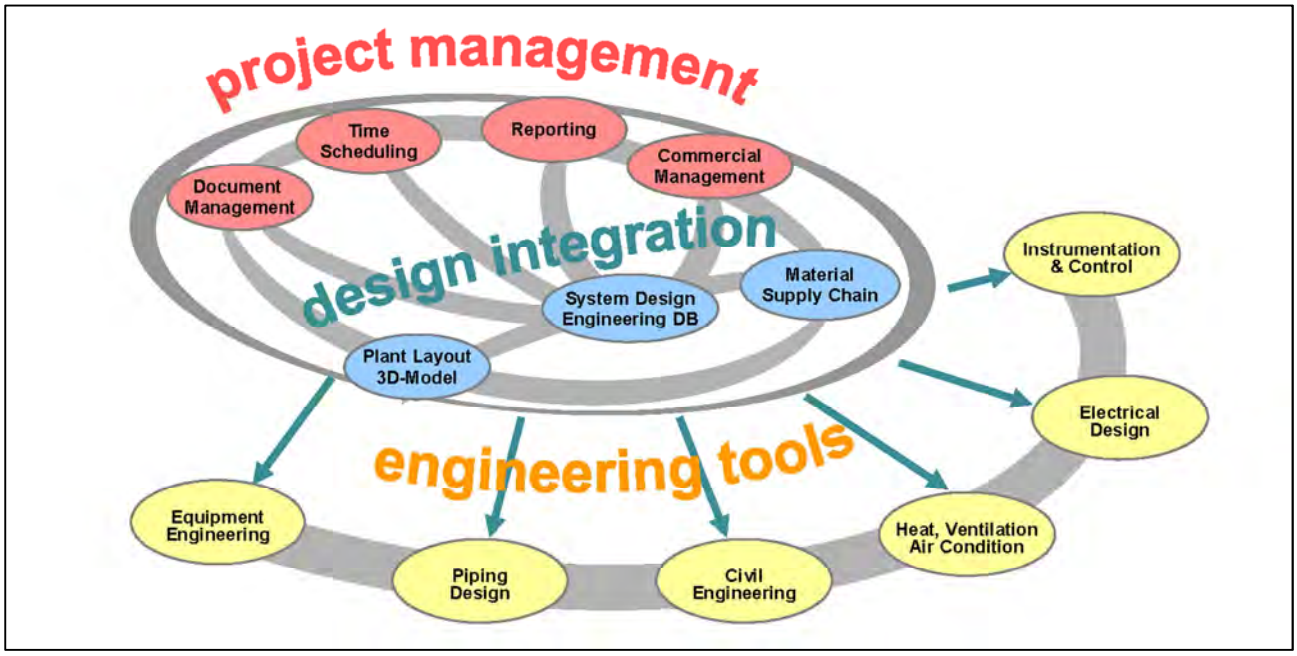

Figure 2-86

2.12.1.1 Project Management Tools

Within the project management space I consider four major categories of IT-solutions, although software providers are offering applications to the market that are capable to support more than just one of these categories. These categories are: Document management, time scheduling, commercial management and reporting.

(1) Document Management:

An EDM (Electronic Document Management) System shall be capable to manage functionalities as described in Section 2.11. Today the terminology has been extended, the IT solutions providers talk about “Enterprise Content Management” (ECM). Early market leaders were ECM Documentum, Laserfiche and Open Text, up to 2006 when Oracle Corporation (with Oracle Content Management) and Microsoft (with its SharePoint product family) started a shopping tour and joined with the established leaders. There are standards for ECM such as ISO 27001 and a variety of government and industry regulations, especially when it comes to the handling of sensitive data. The field of ECM is developing continuously, and any further detailed discussion of software developments in this field would be of historical value only just after a year.

(2) Time Scheduling:

Not all time and resources management tools have to have all capabilities as addressed in Section 2.6. Within the EPC industry the clear market leader is Primavera with its products, although Microsoft with its MS-Project software is clearly catching up. Primavera is powerful but complex, it requires trained scheduling experts to really draw the benefits from this tool. However scheduling a large EPC project is complex, thus complex jobs require complex solutions. MS-Project in its light versions is easy going, any project manager or work-package manager can draw a simple schedule without extensive trainings, the software almost explains itself. So acceptance among those who just occasionally have to handle schedules is much higher. There’re possibilities to extract and reintegrate MS-project files out and into Primavera, so sometimes it may make sense to play on both pianos.

Again, the software industry is developing at high speed, other providers on the market evolve and the market may diversify in the coming years. See Section 2.6.2.1 (Time Scheduling).

(3) Commercial Management:

Enterprise Resource Planning (ERP) Systems can do more than commercial management, and SAP as the clear market leader with 25% market share of the world-wide ERP market still dominates the scene, followed by Oracle, Sage, Infor and Microsoft Dynamics. ERP systems such as SAP offer modules for the operation and maintenance of industrial plants, they offer modules for the management of materials (which I consider a design integration tool), they include document management functionalities. To come back to costs management as presented in Section 2.7: Any ERP system will provide the necessary functionalities; the challenge is not in the capabilities of these powerful tools but in the configuration of the software to the individual business processes. A consulting industry with names such as Accenture has grown very successfully around the ERP software providers; just the consulting costs for a corporate SAP introduction quickly rise to a multi-million-Dollar-project.

(4) Reporting:

Reporting requires the integration of data from a variety of different systems. The IT-solution provider talk about “Business Intelligence” (BI), and the idea behind is that the data is transferred from the different applications into a “data warehouse” for further analysis. Such data warehouse solutions are designed specifically for reporting needs and are able to generate reports that the individual (ERP) applications are not designed for. The market for BI-solutions is in permanent move, with take-overs of established leaders by the big names in IT. To mention some major players: Oracle purchased Hyperion, SAP took over Business Objects, IBM is now owner of Cognos.

2.12.1.2 Design Integration Tools

Let’s take a short excursion to engineering, even though the processes will be explained later in Section 3. Plant engineering today is using electronic design models. The systems design database is a two-dimensional design model for the design of the plant systems, the process-flow-diagrams that define the components of the plant, their relation and their parameters. The plant layout is done in a three-dimensional design model that defines the building structures and the allocation of the plant systems and equipment within the plant. The output of these design models is a material requisition, lists of equipment and lists of material which is the basis for a material management process.

It is pretty clear that such state-of-the-art engineering process only works efficiently when these engineering tools are fully integrated, and the market since years is dominated by the two big players in this field: Intergraph and Aveva. The two have evolved as providers for 3D-plant-design-software (originally Intergraph with PDS and Aveva with PDMS), and many EPC companies may use only one of these 3D-tools, however design integration is certainly the driver to high engineering efficiency.

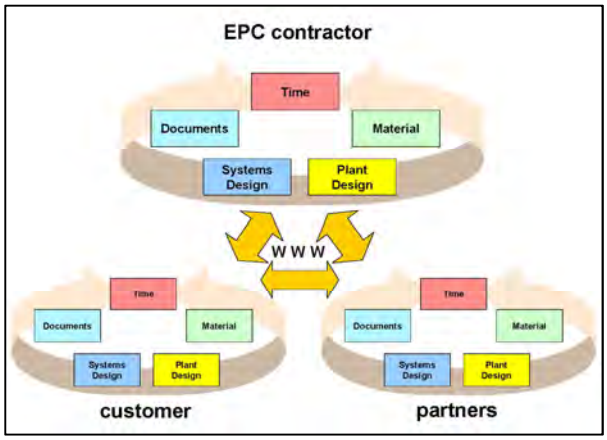

Figure 2-87

Another additional aspect in the use of modern design integration tools is certainly the world-wide access to data. Global engineering is standard in large EPC-projects and this requires software solutions that are able to communicate through web-interfaces around the globe, between engineering offices in the US, in Europe, in China or India. With the client, with the partners. Around the clock, on-line, simultaneous and synchronized. Figure 2-87 illustrates this concept, and as shown this is not only valid for design integration but for the entire spectrum of information management.

5.1.3 Aspects of International Construction Sites

International construction sites have to comply with laws and regulations applicable in the country of the construction site, registration regulations, tax laws, export laws, human resources regulations. Eventually the contractor has a foreign daughter company in the country and may process the contract with the client through the foreign daughter. Otherwise the duration of the project determines whether the activities in the country will require to register a permanent establishment or not, considering eventually valid double-tax-agreements between the country of work execution and the home-country of the company. The responsible site director of a large construction site may quickly become the responsible person for a foreign permanent establishment with all legal consequences. He will be personally liable for any possible violation of national law, and in the worst case, the mother company at the home office does not really have the necessary local legal know-how to support him. He is well advised to seek professional advice from local consultants, legal advisers and fiscal representatives to ensure that his construction site in the foreign country does fully comply with the law. This section does not replace professional consultancy, however it shall give some guideline to the most important laws and regulations that require the attention of the site director (and project director) in an international construction site.

5.1.3.1 Legal status and registration obligations

(1) VAT/ sales tax registration

This registration is generally always required. Wherever a company is doing business in this world, there's a tax authority that requires the payment of sales taxes (Value Added Tax, VAT).

(2) Registration in trade register

In many countries, further registrations beyond the tax registration are required by national law or national regulations, e.g. the registration in a trade register or a registration with authorities that supervise the commercial trade, e.g. a ministry or a department of state or a third-party body like a chamber of commerce. This requires a local expert in order not to forget a specific registration. Some countries are more or less exotic, and quickly a mandatory requirement is overseen.

(3) Registration as permanent establishment

Check the double-tax-agreement between the country of the site and your home-country. Is there any, is it in force, or is it in a status where changes are under negotiation between the governments? Which changes can be expected during the project duration? Double-tax-agreements are agreements between two countries, and the challenge is to find a tax adviser who is an expert for both sides of the agreement. A good local tax adviser may not be fully aware of the double tax agreement especially between your home-country and his own country.

Now, what are the options?

- Project execution without permanent establishment: In many countries a project execution without permanent establishment is only possible for project durations of less than 12 months. In many cases wage taxes are then mandatory for personnel staying longer than 183 days. A VAT registration will be required anyway.

- Project execution with permanent establishment: Once the project duration is longer than 12 month, most countries require the registration of a permanent establishment. A company may have several permanent establishments in one foreign country, or it may have one covering several locations, so be aware of eventual parallel projects in the same country. Generally in such cases wage taxes for personnel will be mandatory from the first day of their stay.

- Project execution through a foreign daughter company: If the company has a foreign daughter in the country of construction, it is an option to close the contract between the client and the foreign daughter. Turnover and profit will then be on accounts of the foreign daughter. Again the double-tax-agreement shall be studied carefully regarding the transfer of profits to the mother company.

(3) Other registrations

There may-be further registrations required beyond those mentioned here and in the proceeding Sections 5.1.3.2 and 5.1.3.3. One example could be the mandatory registration of subcontractors. Generally for any subcontractor the same requirements are valid, as described here, but the contractor may be liable if his subcontractor fails to comply with foreign law. A tax authority may for example request the contractor to pay outstanding tax payments or fines of his subcontractor if he had failed to do so.

These are general aspects that can be encountered in many foreign countries, but careful: Check, what regulations apply in your specific case! In any case you'll have to consider administration costs in your budget, administration costs of the foreign daughter, administration costs for the permanent establishment, for the fiscal representative, for legal advisers or local consultants. Such administration costs may quickly be in the magnitude of 2% of the turnover and thus be in a range that may turn a profitable project into negative.

Checklist International Sites - Taxes

- ☒ Is it required to register in a trade register/ chamber of commerce/ ministry of commerce or trade?
- ☒ VAT/ Sales tax registration (always required!)
- ☒ Is there any double-tax-agreement between the countries?
- ☒ Registration as permanent establishment required? What are the constraints?
- ☒ Consider administration costs for the permanent establishment
- ☒ Appoint a tax (fiscal) representative. What are his duties (required by regulations, additional duties)?
- ☒ Are there local requirements regarding correct invoicing, book-keeping, account-keeping?
- ☒ Which requirements apply regarding the annual report, the tax declaration (corporate income tax), audit obligations
- ☒ Which customs procedures, customs fees and import purchases taxes apply to the import of goods?
- ☒ Any export restrictions (e.g. sensible material), any import restrictions (e.g. used goods)?
- ☒ Does the country participate in the ATA-carnet procedure for temporary import of goods?
- ☒ If not: Clarify the procedure for the transfer of capital assets to the foreign permanent establishment (internal transfer price, market value, pro forma invoice)

Figure 5-3

5.1.3.2 Taxes

VAT, corporate income tax, customs, import purchases tax… I've made good experiences to check the web-sites of industrial trade organizations, chambers of commerce and similar institutions; they often have good information material to get a first idea about the local requirements. Anyway this does not replace the tax adviser.

(1) Tax (fiscal) representative

You will not seriously do your tax declaration yourself. In many countries you're required to appoint a tax (fiscal) representative who will act on your behalf in front of the tax authorities. Typically regulatory required duties of a fiscal representative are:

- VAT registration
- Invoicing
- Book-keeping/ account-keeping
- VAT declarations

You may delegate additional duties to a fiscal representative, such as:

- Registration of foreign personnel
- Waiver from mandatory social insurances
- Annual wage tax declarations
- Corporate income tax declarations
- Wage accounting for foreign personnel

(2) Value Added Tax, Corporate Income Tax

You will have to find out the specific local requirements regarding correct invoicing, book-keeping, account-keeping and annual reporting. Wrong invoices, wrong records formats will cause unnecessary troubles, such things can be avoided if you get professionals involved. Tax declarations will anyway be processed through a tax representative. You may have to check for eventual audit obligations: In case your turnover exceeds a certain limit the auditing by a third party may be required.

(3) Wage taxes, income taxes of foreign employees

See below Section 5.1.3.3.

(4) Import taxes

Goods that have to be imported are generally subject to customs and import purchases taxes. Check whether this prepaid tax is a deductible or non-deductible input VAT.

But what about the temporary import of goods needed on site? If the country is among the nations participating in the ATA-carnet procedure, the temporary import of material can be managed by issuing an ATA-carnet for temporary admission. Customs agents are very familiar with this procedure, but be sure to get the paperwork done correctly before the material starts travelling.

If the country of destination does not participate in the ATA-carnet procedure the only way is the internal sales of material, either by transferring capital assets to the foreign permanent establishment or by selling capital assets to a foreign daughter company. You have to determine an internal transfer price corresponding to the current market value of the goods and issue a pro forma invoice. Eventually a bond or a guarantee will be required. The goods will be kept as capital assets in the books of the permanent establishment and will be depreciated during the period. The return of the goods after the project will be managed again as re-sales to the mother company, based again on a pro forma invoice about the (depreciated) market value.

Be careful about export/ import restrictions. Not all material may-be allowed to be exported from the home country, and eventually there're restrictions for the import of material to the country of destination. The import of used goods, for example special tools for a construction site often is difficult.

5.1.3.3 Human resources

Checklist International Sites - HR

- ☒ Visa/ working visa/ local work permit for workers and employees must be applied
- ☒ Is the worker/ employee requested to report, e.g. at a local police or an immigration agency?
- ☒ Are conditions given that the worker has to pay wage taxes in the foreign country? If yes, register your staff for wage tax
- ☒ Who will prepare the wage tax declaration for the workers? The worker can't do that.
- ☒ Is the worker released from paying wage taxes at home? Double-tax-agreement?
- ☒ Is there a compensation for the worker in case of variations between wage taxes?
- ☒ Apply for a waiver from mandatory social insurance, if possible
- ☒ Apply for a supplementary health insurance, if necessary
- ☒ Is accommodation provided free of charge or are accommodation costs compensated by actual cost or fixed allowance?
- ☒ Are expense allowances and eventual taxes on monetary benefits defined?
- ☒ Are travel policies (corporate policies) defined?
- ☒ Are working times constraint by national law?
- ☒ Are minimum wages imposed by national law?
- ☒ Is temporary-employment-agency work permitted by law, are there contraints?
- ☒ Is there a mandatory participation in insurances, governmental safety organizations, trade unions?

Figure 5-4

Another major area subject to national laws and regulations are human resources. The corporate HR department shall prepare delegation letters for all personnel that will be assigned to a construction site (or office location) in a foreign country. Such delegation letter shall include precise instructions to the employee regarding his rights and his obligations. The major topics are listed below, and again the advice of a professional local consultant will be required when the legal know-how about the respective country is not available in-house.

(1) Obligation to register, work permit

There're possibly various obligations to register before the worker is fpermitted to enter a country for executing work. This includes the application for documents such as

- Visa/ working visa
- Specific work permit
- Reporting, e.g. at a local police or immigration office

(2) Registration for wage tax

In many countries the personnel is subject to wage tax obligations in these cases, however the really valid requirements must be checked specifically, as many countries have deviating regulations:

5.4 Commissioning

Construction is completed, but the plant is still far away from being in a condition to operate. Commissioning a plant is a process that easily takes one or two years. The commissioning process and the important milestones certainly differ significantly, depending on the type of plant. The first connection to grid is a major milestone for the commissioning of a power plant. The approval of licensing authorities to load fuel rods into the reactor, the first criticality – these are milestones that exist only in the commissioning of nuclear power plants. The first release of chemical feed into the systems is a milestone in the chemical industry. Recognizing all the differences between the industries, there're a couple of commissioning principles that are common to all. This section will discuss them, again from the helicopter perspective of a project director. This handbook is a project management handbook, not a commissioning handbook.

5.4.1 Mechanical Completion Management

Mechanical completion management is including a series of activities that require the mechanical completion of construction and installation works on one side, and that are prerequisite for the commissioning engineer to start with the commissioning of mechanical equipment and systems and then the start-up of the plant.

(1) System walk down

System walk downs are scheduled once a mechanical system is considered completed by the erection contractor. At this time, not only all installation works shall be completed, but also all quality inspections are performed and documented – as far as possible and necessary prior pressure testing. The system walk down is generally performed by quality inspectors and technical engineers from three parties, the erection subcontractor, the EPC-contractor, and the client and future owner/ operator of the plant.

Purpose of the system walk down is to determine the actual condition of the system in the field, and to identify deficiencies and remaining work scope to be performed. The open issues will be recorded in a punch list, and this punch list will be worked off systematically by the subcontractor. There may be issues that are mandatory to be completed prior the system is released for the next commissioning activities, the pressure test and the flushing; and there may be issues that may be worked off at a later stage without schedule constraints. There will also be remaining work that cannot be completed prior pressure test and flushing, e.g. the installation of internals in pipes or valves that may be damaged in the flushing process. The punch list system will categorize these open points and is the tool for all parties to systematically ensure the final completion of the system, without omissions.

(2) Pressure test

Pressure retaining systems generally are subject to pressure tests. These tests may be performed using compressed air, or using a liquid (hydrostatic test). The test conditions and test procedures are defined in the applicable codes and standards. The pressure test plan also breaks down the plant systems into pressure test sections according to the various levels of operating pressure in the plant.

In order to execute a pressure test preparatory works are necessary:

- A mobile air compressor or a mobile pump is required to generate the test pressure and it must be connected to the piping system or components with temporary piping, usually at a flange position somewhere in the system.
- There're valves that have to be modified for the pressure test, generally in such case the manufacturer delivers the valve with a set of pressure test internals that will be installed instead of the functional internals.
- The system boundaries must be limited. For this purpose the piping engineer has planned for a flanged pipe section that can be dismantled and replaced by plugs, for example at the inlet or outlet of a pump.
- The system must be filled, e.g. with water when a hydrostatic test is performed
- Measurement instruments must be installed and calibrated to record the pressure test.

During the pressure test itself strong safety measures apply, the safety risk assessment determines which.

Generally no personnel is permitted access within the area of a pressure test. The pressure will be increased gradually up to the test pressure, which is above the operating pressure, and maintained for a defined duration. Any drop in pressure indicates that the system is leaking. An eventual leak must be identified, repaired and the test repeated again.

There's the possibility that due to constraints in the design and layout an individual weld cannot be covered by a pressure test. The code has defined exception rules for such cases and requires additional NDE examinations for such welds. On site we call these welds "golden welds".

(3) Systems flushing and cleaning

Systems are being inspected for cleanliness before they're closed. Even though – I don't know how many rags, even hammers in the systems I had encountered in my life. Flushing the systems with water shall remove all the dirt that otherwise will pollute or damage the sensible parts of a plant, the pumps, or – worst case – a turbine. Acid cleaning is another method; it shall clean the internal pipe surfaces, especially where pipe welds have been produced without having the accessibility to backweld the root.

Again there're preparatory works required, such as installation of temporary pumps and temporary supply and discharge pipes, the supply of liquid, or the dismantling of sensible internals. There're procedures for the preparation, there're procedures for the execution, safety procedures and risk assessments, there're checks and inspections, and procedures to dry the systems afterwards.

(4) Final assemblies

The system is leak-proof and clean, all the temporary supply and discharge pipes and temporary pumps removed. Valve protections and plugs have to be disassembled and the final valve internals installed. Flanged pipe connections have to be reinstalled that were disconnected for pressure test or cleaning. Final gaskets and sealings have to be installed where provisional parts had been used for the "rough" commissioning. Insulation works must be completed in those areas where the insulation has been left out to access welds for inspections or valves for assemblies.

(5) Certificate of completion (Milestone 7)

The punch list system will include all these final work items, and one final day the last walk-down will confirm the final completion of all works. The remaining inspection records from pressure tests and systems cleaning have been included in the final documentation, the documentation package is complete. The certificate of completion can be issued.

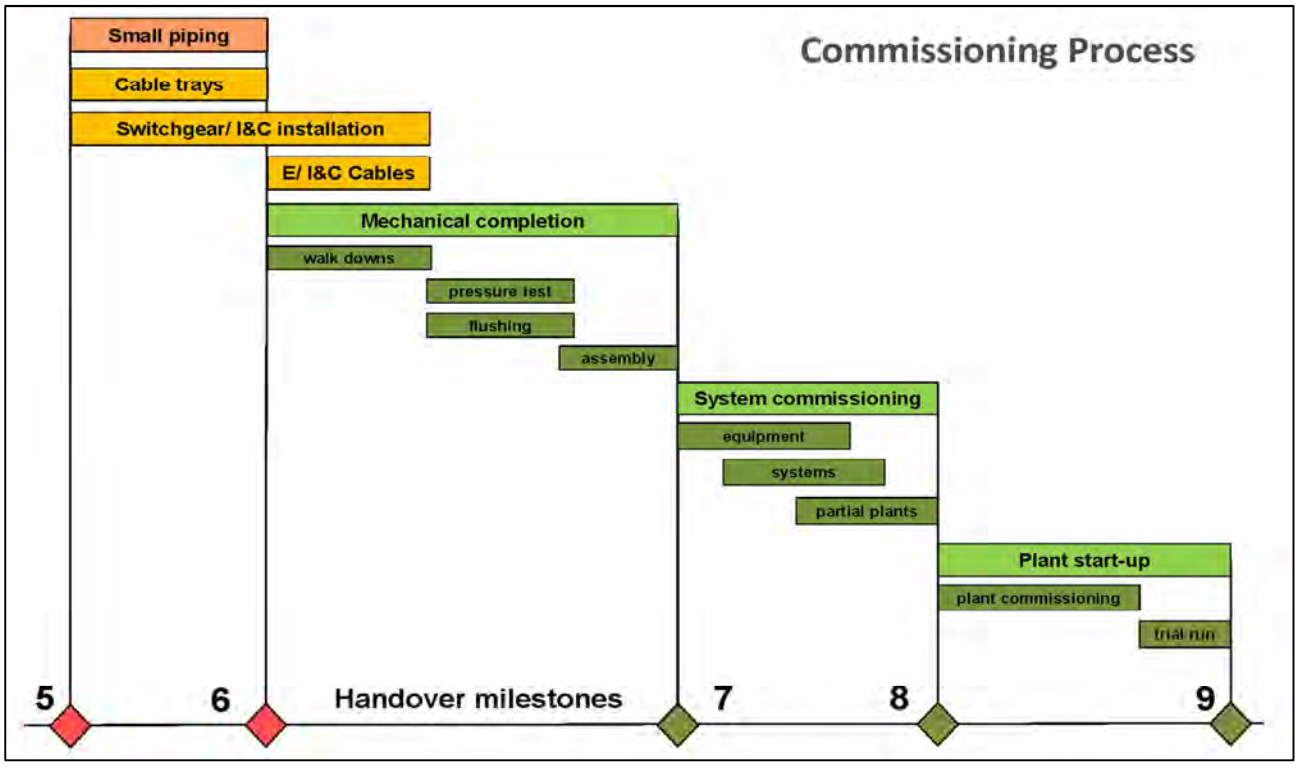

Figure 5-11

5.4.2 Commissioning Program

Commissioning means gradually putting the plant into operation mode. This process starts on the lowest level, for individual equipment and components, then for systems, partial functions of the plant, for the entire plant. Putting into operation requires that all operations procedures, all maintenance procedures are implemented and the personnel is trained to operate and maintain the systems. This program is very comprehensive and as already mentioned in Section 5.1.1 the commissioning manager will take over the lead on site at an appropriate time, at latest with the date of final completion (Milestone 7).

5.4.2.1 Commissioning documentation

Commissioning procedure for mechanical equipment (example)

Equipment number/ identification code
Equipment description
Schedule, time schedule reference
Location, access
Preconditions (other systems commissioned)
Preparatory work (e.g. lubrication, initial maintenance actions, connections)
Testing procedures & acceptance criteria
Status of equipment after commissioning
Applicable documentation
Applicable safety procedures, risk assessment

Figure 5-12

Commissioning procedures sounds too easy. Commissioning manual sounds better, but the documentation required during the commissioning is even more comprehensive. What is required?

(1) Commissioning procedures/ manual

The commissioning procedures describe the activities to be performed during commissioning for each piece of equipment, for each system, for the partial plant functions, for the total plant. See Section 5.4.2.2. Figure 5-12 depicts an example of the content of a commissioning procedure for mechanical equipment. The commissioning manual is certainly subject to client review and client approval, as the commissioning procedures will define all intermediate system tests and their acceptance criteria that finally lead to the total plant acceptance.

The commissioning schedule is the document to plan and control all these activities and the logical interfaces between them, but generally the detailed tracking and control of all commissioning activities is performed with the appropriate IT support, electronic databases, workflows and reporting tools. The very basic sequence shown in Figure 5-11 simplifies the reality. Typically commissioning activities are scheduled much more in parallel as shown, e.g. the commissioning of equipment may start already at a much earlier stage.

(2) Operation procedures/ manual

As said above all the operation procedures/ the operation manual of the plant must be available at the time of plant commissioning. Available means again reviewed and approved by the client, and probably also by the licensing authorities that are in charge to issue the operation license.

(3) Maintenance procedures/ manual

The same is valid for the maintenance procedures/ manual. Initial equipment commissioning includes initial maintenance, e.g. lubrication. Instructions for regular maintenance have to be respected, as soon as individual equipment is operated, otherwise suppliers' warranties are at risk.

(4) Training documents

The personnel that maintains and operates the equipment and the plant systems must be trained and qualified in accordance with all manuals and regulatory requirements that are included in the operations license.

(5) Plant documentation

For commissioning as well as for operation and maintenance of the plant, the complete engineering documentation (as-built) and the final documentation from manufacture & construction must be available.

5.4.2.2 Commissioning process

The commissioning process generally follows the logical sequence from smaller equipment to subsystems, systems to larger operational complexes of the plant. These are the main phases of the commissioning process after mechanical completion:

(1) Equipment check-out

This is the initial configuration and testing of individual equipment, e.g.

- Check of pipe hangers and restraints (in cold condition)
- Check of final alignment of equipment
- Initial lubrication
- Check of mechanical blocks, setting of limit switches, overload settings
- Electrical test of circuits (electric cables, wiring, termination checks)
- Uncoupled test run of motors
- Initial operation (dry run) of rotating equipment, coupled run of motors
- Rotating equipment vibration checks and adjustments
- Calibration of individual instruments and devices
- Checking of equipment grounding
- Functional test of circuits, function of instrument loops between the screen (man-machine-interface) and the device
- Functional checkout of components and equipment

(2) System testing

With the individual components, equipment and circuits checked out, the individual systems can be tested. These tests are performed either as dry runs or using test material, as far as possible, although systems may be started up to the operating temperature and operating pressure. Activities during system testing include among many others:

- Verification of the system equipment functions
- Verification of the electrical control functions of a system
- Check of pipe hangers and restraints (in hot condition)

(3) Start-up

The start-up of the integrated plant operation will include the operational product feed in order to demonstrate the integrated function of the plant (or partial plant). The start-up includes activities such as:

- Functional verification of equipment and system operating parameters
- Demonstration of the production of the final product
- Functional operation tests in normal and abnormal operating conditions
- Adjustments of parameters, optimization of systems and processes
- Execution of performance test

The logic of the commissioning process is certainly also determined by the functions of the plant. Auxiliary supply or discharge systems that provide the plant with water or fuel or electric power certainly have to be in full operation when these auxiliary functions are needed for the operation of the core plant functions. A cooling system shall work before the system that generates the heat is put into operation. A pump cannot be put into operation when the corresponding electrical motor has not been tested.

I won't go into any further details of commissioning, this would fill another book. For those interested in more information on commissioning, I'd recommend this book; it contains some good checklists and well-arranged descriptions of commissioning activities: Plant Project Engineering Guidebook for Mechanical and Civil Engineers, Morley H. Selver, CASTI Publishing Inc., Canada, 2002.

5.4.3 Handover to Owner/ Operator

The overall plant performance tests are the final acceptance tests of the commissioning process. During these tests all operating conditions of the plant are tested, the normal as well as defined abnormal operating conditions. It may be followed by a trial run of a contractually defined trial period, where the contractor has to proof that the plant is operating reliably during a longer period of time.

With successful completion of all tests and the trial run the plant is handed over to the client for commercial operation. The handover document is a

preliminary acceptance certificate, from that date the warranty period starts. The client will pay his final invoice, however a warranty bond may be retained. It is not earlier than the end of the warranty period that the client will issue the final acceptance certificate and release the retained money of the warranty bond.

With handover of the physical plant also all documentation and electronic data will be handed over, this subject has already been addressed comprehensively in Section 2.11 and Section 3.2.3. The project manager will close out the project and demobilize the construction site and the project organization. Section 1.1.2.5 has already addressed these activities.

The project is over. Construction and commissioning is completed, the plant is operating. The client is satisfied. You walk across the plant, for a last time, and every component, every structure has a story to tell. You climb the staircase, the one that has been added on client request late during engineering and that caused so much re-engineering in the field after you had to climb across beams and pipes to access it. You see the green coloured columns of the steel structure and remember the day when the paint peeled off in large sheets. Remember the pump over there; it caused the plant stand still for three days during commissioning because one stupid gasket was missing in the spare parts. You, the project manager, picked it up personally at the airport when the courier arrived.

You remember when you met the client for the first time, is it already five years ago? You had a bid presentation and at the end the client gave you the feeling that he never ever will award the contract to you. He did. You met a lot of people during these years. Some remained nasty until last week, like this lawyer who was trying to convert every micro-change into a claim to you, and yesterday with the final release of liens and claims obtained he suddenly smiled and pat you on the back. Or the project manager from the consortium partner: how many evenings did you spend in the office discussing the plans? You became real friends, he invited you to his home. His wife was pregnant when you met for the first time. A boy. Now it's already a big boy. The farewell party with the client. It was so emotional. Across all cultural differences you came so close. You gathered around the large round table and together with the client director you threw Chinese noodles into the air, as high as to the ceiling of the restaurant hall. Intercultural experiences.

It was a huge project. And definitely not easy at all. It was a great team, wonderful people working for the same goal. People from different cultures, on different continents, with different background, with their own history and their own stories. They mastered the challenges, all together. Now the project is over. You walk across the plant, for a last time, and you think: being the project manager in an EPC project is an exciting and rewarding job. This is the damned best job in the world!

PROJECT TEAM

Project Management Handbook for EPC

Engineering – Procurement – Construction

This is the most comprehensive collection of know-how for project managers in the process industry available on the market:

- ✓ Energy: power plants, thermal power generation, nuclear power
- ✓ Oil & Gas: refineries, petrochemical plants
- ✓ Chemical industry

Based on the recognized project management standards such as PMI ® (PMBoK®) and ISO 21500 (2012)

Proven work practices, tools, methods and procedures from real projects, including large scale “mega”-projects

Up-to-date, structured, thoroughly – and still comprehensible and entertaining.

- ✓ more than 200 pages of project management experiences
- ✓ more than 150 figures, graphics, checklists, many in color

The MUST HAVE for all professionals engaged in EPC business.

www.project-team.org

First Edition – August 2014
ISBN 978-3-00-046425-6

RRP 79.90 €