Beyond Buildability: Operability and Commissioning of Industrial Facilities

By Maurini Elizardo BRITO, Raphael de Oliveira Albergarias LOPES,
Luiz ROCHA and Eduardo QUALHARINI

Abstract

Industrial projects are growing bigger and more complex, producing new challenges for their completion. As such, project management, and the perception of project success, must be aligned with a new paradigm: the plant's completion is not enough. It is necessary to deliver the benefits envisaged during the project formulation, including successful commercial operation.

This new paradigm requires new processes and behaviours related not only to engineering best practices but also to new managerial approaches. Closure is pivotal throughout the life cycle when the facility transitions from plant completion to start-up, followed by the ramping up of operations. To deliver what was previously planned, three main drivers must be in place: quality of the scope definition; alignment of the business strategy; and operability of the asset delivered.

Traditionally, commissioning has been considered an activity that is executed just before the operations take over from the start-up systems. Increasingly, it has become a comprehensive and systematic process to verify and document the systems of a new or remodelled plant functioning as designed to meet the owner's requirements. Thoroughly planned and executed commissioning has become critical to allow the facility to operate as intended.

The purpose of this paper is to demonstrate that a focus on operability and the commissioning of new or refurbished facilities represent opportunities for owners and operators to eliminate and mitigate exposure to numerous risks and increase the chance of success for the facility life cycle and the likelihood of satisfying the operational needs and requirements.

1. Introduction

The context of industrial operations has been changing fast in the last decades. Pictures of plants from the beginning of the last century show a reality that is already difficult to recognize, so many and so deep are the technological, organizational and environmental differences from the present standards. Such differences widened from the 1950s onwards, being identifiable amongst others by four elements: the size of the plants; the complexity of the production processes; the production costs (both capital and operational expenditures); and the performance requirements (product and process). At the same time, the market has become increasingly demanding and dynamic, requiring fast and accurate responses. Slippage of just a few weeks in the time-to-market of a product may cause a missed window of opportunity and serious financial losses to a company. Merely one ill-conducted project that fails to deliver as planned (and needed) may put a company's survival at stake.

This modern context is especially demanding when companies deal with new or extensively modified production assets that concentrate very high capital demands and, at the same time,

need to address the main business objectives. However, the construction industry presents a historical difficulty in delivering running facilities. This issue has been extensively discussed by the Construction Industry Institute (CII, 2004), an international forum of the building industry. The CII states that:

> *Project Management and the perception of project success must be aligned with a new paradigm: mechanical completion is not the project objective, successful commercial operation is.*

The challenge of successful commercial operation requires the replacement of conventional management and engineering practices with new models that can assure the integration between the effort of creating the production asset and the business context. This need becomes obvious and critical in the last phase of the project, when the asset must demonstrate its conformity to the specifications and its capacities and produce as planned. Although it could have seemed rather simple to our grandfathers, or at least not an essential issue, presently it is not feasible to overcome the challenge without proper methodology, best practices and thorough project organization. Without them, the risk of failure in achieving business objectives due to a poorly delivered or underperforming asset increases dramatically.

From an industrial project management standpoint, there are at least three major factors influencing that context directly and decisively:

- Scope definition
- Integration between business objectives and project strategy/planning
- The operability maturity level of the project

For reasons of space, the first two will be briefly outlined as an introduction to the analysis of the third one.

2. Scope definition

The handover of an industrial facility to its customers/operators requires a sound definition of the conditions under which that critical activity will take place. After all, the facility is the main deliverable and the *raison d'être* of the project. However, due to insufficient WBS/SOW detailing and/or low-quality technical specifications, those conditions are frequently unclear, creating responsibility issues, contractual claims and, sometimes, inadequate scope at the end of the project.

The lessons learned from big industrial projects point to complexity as one of the root causes of this recurrent problem. The project team focuses spontaneously on the costlier and more complex deliverables (which are not few). The "lighter" ones receive less attention than would be advisable. Compared with the main deliverables, many elements, or work packages, connected to the start-up/handover of industrial facilities are actually small (in terms of cost and time). Since they need specialized knowledge (which is frequently not available in the early phases of a project) for identification and specification, those elements are usually missed or not weighed correctly.

As an example, suppose that a safety valve fails during the running tests, seriously affecting the start-up process and the subsequent ramp-up. The problem could be easily solved by the

availability of a spare valve. Because such an item is so unimportant in the large WBS picture, it "remains under the carpet" until the crisis occurs. Usually, the development of a WBS does not take into account how critical the deliverables are for the operation of an industrial facility.

As a best practice, it is advisable for the team in charge of constructing the WBS to incorporate commissioning experts and for the weighting of the commissioning deliverables to consider not only their direct cost but also their impact on the start-up/ramp-up of the facility.

3. Planning integration

An industrial facility, new or remodelled, is a production asset embedded into a capital project. Usually it is not the only project deliverable, although, frequently, it is the main one. Beginning production is certainly a major milestone, which is decisive for project success as well as for the strategy of the sponsor organization business. Therefore, project planning must take into account some specific points:

- Avoid the rather common mistake of considering the project as an isolated entity by aligning the start-up and ramp-up phases with operations and using it as the starting point for the rest of the project planning;

- Realistic dimensions of the start-up/ramp-up activities, avoiding another common error: building the time schedule from the first day on and, at the end, crushing the last (rather unknown) activities to fit them into the time frame of the project;

- Risk mapping/assessment taking into account the entire business context and not only the design/procurement/building phases;

- Clear definition of the transfer point of the facility, that is, the condition that will define and allow the transfer of custody from the project team to the client's team (users/operators).

These are typically early project actions, and the key issue is their omission or postponement to later phases when the facility implementation is quite advanced and the cost of realignment and changes becomes very high, even prohibitive. The recommendation is the same as given before: do not underestimate these aspects when preparing the project baseline and follow the advice of commissioning experts/users/operators/customers.

4. Operability and commissioning

Every project needs two types of work processes: those related to planning, coordination and control of all the project work (management) and those related to the specification, procurement, creation and evaluation of the project's product. Management processes are applicable to most projects with minor adjustments; product processes vary according to the nature of the product.

For industrial facilities, it is possible to organize the work necessary to specify, procure, implement and evaluate the product into four main processes:

- **Engineering** – the process of progressive specification of the facility, from the functional specifications to the "as-built" condition of the engineering documentation;

- **Materials** – the process of supplying and managing all the materials needed to fabricate, build and assemble the facility, in accordance with the engineering specifications;
- **Construction** – the process of the physical build-up of the facility, in accordance with the engineering specifications, and using the supplied materials;
- **Commissioning** – the process of testing and starting up the facility to verify its performance and transfer it to the final users/operators, in accordance with the engineering specifications.

Entities like the CII and International Project Analysis (IPA)[1] compile and recommend as value-improving practices (VIPs) a set of procedures that can ameliorate the results of those processes and increase the chances of project success. Amongst those, one of the most effective is constructability.[2] The name may give the false impression of a VIP related to the construction process only. In reality, this best practice comprises a critical review of the design, construction and start-up of a plant to identify and select the most effective methods of implementation. In this sense, a subgroup of constructability is operability – a set of checkpoints intended to assess how project planning deals with the start-up and "go live" of the facility.

The formal definition of operability and its checkpoints may vary from company to company. As an example, we present below Petrobras's (2008) approach. Petrobras's definition of operability is:

> *The capacity of a facility to comply with its specified performance requirements while operating in steady and reliable conditions.*

The checkpoints that accompany this definition are:

1	All the operational systems are handed over to the operator, with no pending items
2	The operation and maintenance documentation is updated and available to the users
3	The operation and maintenance crews are trained
4	Spare parts, special tools and consumables are available and stored on-site
5	Temporary facilities are removed, the plant is ready for normal operation and energies are under the full control of operators
6	The plant complies with all the applicable rules and regulations, and all the permits and contracts needed for normal operation are available
7	The external interfaces needed for the plant's operation are available
8	The maintenance management system is ready and available for the users

Table 1 – Operability checkpoints (according to Petrobras)

These checkpoints are typical and illustrate how to incorporate the paradigm "project success is the commercial operation" into a project methodology for practical use.

It is clear that operability checkpoints are verifiable only at the end of the project. On the other hand, it is also clear that they represent the apex of development of both the product and several management activities. In other words, either the operability aspects are taken into account from the beginning of the project or it will be very difficult (or even unfeasible) to reach the goal. In this sense, the recommended guidelines are:

[1] A consultancy company dedicated to industrial projects (www.ipaglobal.com).
[2] Constructability is one of fifteen VIPs recommended by the CII.

- To define clearly in the product's requirements and in the project's opening documents the operability conditions that will be used as a reference for the future transfer of the facility;

- To define milestones for operability compliance verification (usually, but not necessarily, linked to constructability workshops) in each phase of the project;

- To integrate operability requirements into the project plan, making them part of the project planning;

- To commit all the stakeholders involved in the facility's design, construction and operation to take part in operability workshops, avoiding the common tendency to consider that subject as an "operator-only" concern.

This brief description shows that operability should be a major concern for managers of industrial projects. Given the broadness of the operability approach and its consequences, this value-improving practice must be included in the work scope of integration management.

Compliance with operability requirements addresses the four product development processes, but commissioning, by its own nature, is the operability tool of choice. Operability encompasses a set of IPMA (2010) competences: technical (project management success; project requirement and objectives; project organization; teamwork; scope and deliverables; and close-out), contextual (permanent organization; business) and behavioural (leadership; engagement and motivation; results orientation; negotiation; and reliability).

Just a few years ago, it was usual to say, "a construction is never completed, but abandoned". Commissioning or any similar activity was secondary and subordinate to building and construction. In the words of Bendiksen and Young (2005):

> *Traditionally, commissioning has been viewed as an activity that is executed just before Operations take over the systems for start-up.*

In other words, commissioning was a minor activity considered at the end of the project and not engaged in the actual start-up of the facility. The understanding that it entailed something else evolved gradually, beginning with the identification of a set of activities recognized as important to a safe and effective start-up (pre-commissioning). Then came the acknowledgement that commissioning documentation is part of the engineering process (i.e., part of the engineering deliverables) and that the realistic inclusion of commissioning in project planning contributes to time and cost gains.

Finally, commissioning was identified as an independent product development process at the same level as engineering and construction. Authors like De Souza and ScottMadden (*apud* Gandra and Lopes, 2009) see commissioning as one of the project's phases. However, this approach does not take into account the nature of commissioning, which is real work performed simultaneously with other product development processes. Adding to this concept, Jeanette (2011) defines commissioning as:

> *A comprehensive and systematic process to verify and document that systems of new or remodeled facility function completely as designed to meet the owner's requirements.*

Wilkinson also understands commissioning as a process (2009):

> *The commissioning process is the quality assurance in building construction.*

These views definitely position commissioning as a workflow defined by its own method, a methodology that links many transformation activities into an integrated effort and a final goal (by the way, that is what allows the existence of commissioning companies – specializing in a work process, not in a period of time). This misunderstanding originates, probably, from the word itself. Commissioning has been used to name the last part of the execution phase of a project: the set of acceptance tests of a plant and the whole process of preparing an industrial installation for operations. To overcome this obstacle, let us use Petrobras's definition as an example: "commissioning designates the whole process". In America, the set of performance and acceptance tests usually known as commissioning is named "pre-operation and start-up" and does not include any phase called "commissioning" in project planning and timelines. Nevertheless, the key to defining commissioning in sound terms is the principle of "one-name-to-each-thing-and-each-thing-with-one-name".

Commissioning flows through the project phases. As a reference, if the project is organized according to the FEL[3] approach, then the commissioning process extends through Phases III and IV, as shown in Figure 1.

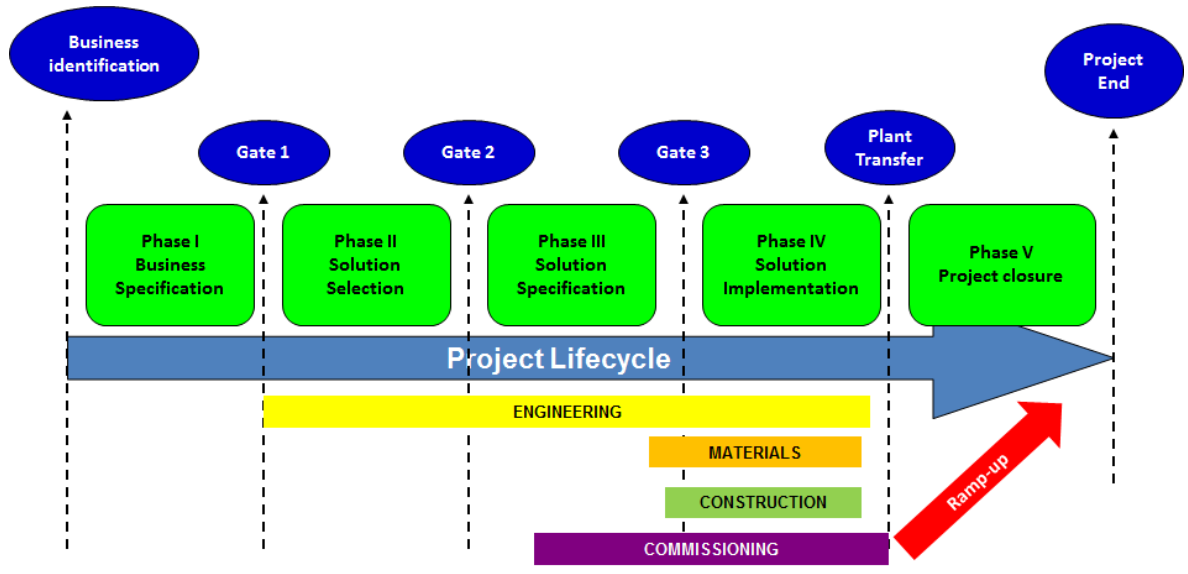

Figure 1 – The commissioning process in the project life cycle

[3] Front-end loading (FEL) is a methodology recommended by the IPA to organize the development of industrial projects. Its main phases are business definition; solution selection; solution specification; and solution implementation.

Figure 1 shows the superimposition of four product processes. The transfer of the project scope to the client occurs at the end of Phase IV, when the operability conditions are verified and accepted. Ramp-up (production increase up to the steady-state capacity), the operator's responsibility, occurs in parallel to the project's closure. This model allows the definition of the transfer conditions according to the client's needs. It is possible, for instance, to select a performance level that will define the transfer point or to choose which parts of the facility ("operational systems") will be transferred in running condition (ready for ramp-up) or commissioned directly by the operators.

As such, the commissioning process is an instrument for operability, although it does not provide answers to all the checkpoints. In the list from Table 1, commissioning delivers the first item and manages the delivery of the others, in more or less detail, according to the approved procedures. It is important to note that commissioning activities do not mean the automatic transfer of the facility. It is still necessary to fulfil other operability conditions, as specified at the beginning of the project. Although in some projects the responsibility for operability conditions remains with different members of the management team, experience shows that this is not the best option. Either the commissioning manager or the integration manager (i.e. the project manager himself) must take care of operability issues.

A sound methodology is paramount for commissioning success. Actually, an effective methodology distinguishes modern commissioning from older approaches that took into account only a set of field tasks that were loosely connected with the rest of the project and with one another. Several methodologies may be available to that effect, but all should comply with three basic guidelines:

- Operational vision – the facility is perceived as a running production process, not as an object to be built;
- Systems approach – the facility is decomposed into a set of operational systems, logically connected and capable of performing a specific part of the production process;
- Sequencing – commissioning tasks are organized and performed in a rigid sequence from independent components ("commissionable items") to the full running facility, without the possibility of interchange.

From these guidelines, any commissioning methodology will organize six main activities (also called sub-processes):

- Management – includes all the work needed to define the project's commissioning strategy, plan the commissioning process, coordinate its execution and control the results;
- Commissioning engineering (also known as documentation) – includes all the work needed to produce the documents that support the commissioning field tasks;
- Pre-commissioning (also known as conditioning) – includes all the work needed to assure that all the commissionable items,[4] loops[5] and sub-systems[6] are ready to run safely and begin their live tests;

[4] All physical or logical isolated components that perform a process function.
[5] A set of integrated physical or logical elements that perform a process function.
[6] A subset of an operational system, capable of performing the same process in a reduced or partial way.

- Preservation – includes all the work needed to assure that the facility equipment and materials are delivered to the operators as they were received from the vendors;
- Pre-operation and start-up (PO&S) – includes all the work needed to assure that all the facility's systems operate safely and steadily and to assess their performance;
- Assisted operation – includes all the work needed to assist the operators in the first days/weeks after the transfer of a system to assure safe and steady operation.

Two elements are also necessary for successful commissioning (and for achieving operability): team qualifications and stakeholder commitment. The importance of training does not need to be emphasized. Far trickier is to convince stakeholders and management officials about the gains afforded by the application of operability and commissioning methodologies. The temptation to maintain old practices is strong and it is the project manager's responsibility to explain the benefits of the new approach, providing benchmarking evidence and using his persuasion to obtain the necessary commitment. In addition, the project manager should follow up the stakeholders' commitments and the application of the methodologies to deliver a running industrial facility, not an abandoned one.

5. Conclusions

Traditionally, commissioning has been considered to be an activity that is executed just before operations take over the systems for start-up. The consequences of this view are:

a) Industrial projects lacking integration with the capital project that they are part of and deliverables not satisfactorily aligned with the business needs;

b) Value destroyed by this state of things and a new paradigm needed to overcome the problem.

More and more, commissioning has become a comprehensive and systematic process to verify and document the systems of a new or remodelled plant functioning as designed to meet the owner's requirements. Thoroughly planned and executed commissioning has become critical to allow the facility to operate as designed. As such:

c) The new paradigm includes addressing scope and time management and especially re-evaluating the way in which the product is developed and implemented;
d) Commissioning is not a project's life cycle phase but a work process and an instrument for achieving operability;
e) Operability shall be considered a responsibility of integration management;
f) Applying commissioning requires methodology, team qualification and stakeholder commitment.

The purpose of this paper is to demonstrate that a focus on operability and the commissioning of new or refurbished facilities represent opportunities for owners and operators to eliminate and mitigate exposure to numerous risks and to increase the chance of success for the facility life cycle and the likelihood of satisfying the operational needs and requirements.

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About the Authors

Maurini Elizardo Brito

Rio de Janeiro, Brazil

Maurini Exizardo Brito is Director of RUMAR Consultoria e Engenharia Ltda.; Visiting Professor at Universidade Federal do Rio de Janeiro (POLI/NPPG); Visiting Professor at Fundação Getúlio Vargas (FGV); Member of the Advisory Board of Albion Capital. He is a naval architect and marine engineer, with an MBA degree in Organizations Management and Marketing and a MS degree in Production Engineering. He is a First Assessor and Project Director of IPMA Brasil; PMI Member; Member of Sociedade Brasileira de Engenharia Naval (SOBENA).

Maurini has more than 30 years of experience in the shipbuilding, chemical and energy industries; 25 years of management experience in projects of oil platforms, thermic and biodiesel plants, combat and research vessels, amongst others; management experience in transnational projects; commissioning specialist. He was eleven years at the Brazilian Navy (Engineering Branch); twelve years at Michelin Tire Corp.; thirteen years at RUMAR, acting as senior consultant for project management, including nine years as Petrobras senior consultant for commissioning and project management; ten years as project management professor.

Maurini lives in Rio de Janeiro and can be contacted at maurini.brito@poli.ufrj.br

Raphael de Oliveira Albergarias Lopes

Rio de Janeiro, Brazil

Raphael de Oliveira Albergarias Lopes, M.Sc., MPM is a Professional Coach, IPMA-C, PRINCE 2 - Practitioner, PRINCE 2 - Foundation, PMI-PMP, PMI-SP, Orange Belt. National president of IPMA Brasil, he is lead assessor for IPMA certification in Brazil and development director for LATNET IPMA.

Raphael has over 13 years' experience in project management and consulting, including participation in more than 60 projects, from implementation of mega projects in upstream and downstream, ERP implementation and Business Process Model. He is founding member and President of IPMA Brazil. Brazilian Leader of Review Group of the ICB 4.00. IPMA Lead Assessor for 4-L-C IPMA certification. Partner of IDGP (Instituto de Desenvolvimento em Gestão e Projetos).He is visiting Professor at

Bordeaux, USP/FIA, UERJ, FGV, IBMEC, UVA and UFRJ. Doctoral Student at FEA/USP and Université François Rebelais de Tours. International speaker. Books published: *Project Management Office, Program and Portfolio Practice* - publisher Brasport - 2012 and *National Competence Baseline Brazil* - IPMA Brazil - 2012.

Bachelor in Business Administration. MBA in Project Management - UFRJ. Master in Business Administration - FGV. PhD Student in Business Administration at ¬Université François Rabelais de Tours, France and FEA/USP. Professional certifications: Professional Coach (SBC), IPMA-C, PMI-PMP, PMI-SP, PRINCE 2 Practitioner, PRINCE 2 Foundation and Orange Belt. First in Brazil to put together the most globally recognized certifications in project management. Specialties: Project Management Strategic Management Business Process Modeling ERP implementation projects.

Raphael lives in Rio and can be contacted at presidencia@ipmabrasil.org

Luiz Fernando Alves da Rocha

Rio de Janeiro, Brazil

Luiz Fernando Alves da Rocha has 35+ years of experience in the industry and business consulting. Luiz worked with Andersen Consulting and Delloite in the USA and Europe when he had the opportunity to manage multi-cultural and geographically dispersed projects in Latin America, North America and Europe. In Brazil he worked with Dinsmore Associates and Petrobras. Luiz is an engineer by background, MSc. in industrial engineering from UFRJ – Brazil, PMP-PMI and IPMA certifications. He is also a published author with two previous books, *Business Metamorphosis*, in Brazil, and *Mount Athos, a Journey of Self-Discovery*, in the USA. Luiz can be contacted at luizrocha@poli.ufrj.br

Dr. Eduardo Qualharini

Universidade Federal do Rio de Janeiro (UFRJ)
Rio de Janeiro, Brazil

Dr. Eduardo Qualharini's background includes Civil Engineer 1973 UFRJ/Structures & Construction; Esp. Sec of Labor 1976 & Production Civil 1984; Esp. High Studies in Planning and Strategy War College 1992 ; M.Sc. Architecture 1992 & D.Sc. Production Engineer 1996; and Post-doctorate in Civil Production 1998.

Dr. Qualharini has more than 40 years of experience in Production Planning, Construction, Security, Accessibility and Ergonomics Labor, in over 300 projects undertaken in the areas of Civil Engineer and Production. He was coordinator project manager for the General Management of Enterprises in the 1980's (IESA) and director and coordinator of projects in civil and industrial services in Brazil and abroad, with a cumulative value of more than US$ 2 billion.

He is Full Professor at Universidade Federal do Rio de Janeiro (UFRJ), Program Environmental and Civil Engineering, and Coordinator of NPPG / UFRJ - Center for Research on Planning and Management, since 2003. He is First Assessor of IPMA Brasil; Member of Associação Brasileira de Normas Técnicas (ABNT); Member of Editorial Board of the Journal MPM Project Management; regular reviewer of the journal GEPROS - Faculty of Engineering and Faculty STEP UNESP; and member of the editorial board of the journal Focus on Extension.

Dr. Qualharini can be contacted at Eduardo qualharini@poli.ufrj.br