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Abstract

This paper reviews four project life-cycle models presenting some interests in the management of technical projects. It is shown that each life-cycle model has some specificity that can explain a particular aspect of a project or of the duty of a project manager. Because the reality of a project is always complex, it cannot be embraced by a single model; therefore, several complementary models are required.

Keywords: feasibility phase; project life cycles; product-project dichotomy; technical projects

It is quite difficult to attribute the concept of project life cycle to one author in particular, since this concept has gradually derived overtime. However, *A Guide to the Project Management Body of Knowledge* (*PMBOK® Guide*) (PMI Standards Committee, 1996) proposes some definitions or models; others can be found in the *Project Management Handbook* edited by Cleland and King (1988) and in many project management textbooks. As project life cycle also is handled daily by project management practitioners, additional or alternative models can be observed directly in real-world projects. While going through these model proposals, one can remark that each author in some way enforces what is specific to the particular context for which the model has been made. For instance, a well-known project life-cycle model proposed by the U.S. Department of Defense emphasizes the aspects related to the demonstration of the feasibility and viability of the project (two phases), while the specification and the execution of the project consist of one phase each. Another project life-cycle model proposed by Muench for information systems projects (*PMBOK® Guide*) insists on taking into account the recursive processes often associated with these project contexts.

The aim of this paper is to review project life-cycle models, specifically those presenting some interests in the field of technical projects. Reviewing all the models that have been proposed during these last two or three decades would be a cumbersome endeavor; hence, the authors limited this paper to an overview of the major project life-cycle proposals—before proposing additional models.

The life-cycle models reviewed in this paper are organized around five broad approaches, in an attempt to appraise the benefits of each. These approaches are:

- Straightforward project life-cycle approach;
- Control-oriented project life-cycle approach;
- Quality-oriented life-cycle approach;
- Risk-oriented project life-cycle approach;
- Fractal project life-cycle approach.

The referenced papers and practices have been summarized, are believed to be appropriate, and may, therefore, not truly reflect the original authors' aims. Reference to the information source is provided when available for more complete coverage.

Straightforward Approach to Technical Project Life Cycles

Technical projects can be broken down into phases, also called stages or steps by some authors. In this paper, the authors will not differentiate between these three substantive; the term "phase" is preferred. These phases can be divided into subphases, then sub-subphases, and so on. The number and labels of these phases are deeply dependent on the field for which the model has been made. Obviously, the breakdown into phases of a small project is different from the ones used for large-scale projects. The phasing of engineering and construction projects also are different from those used for the development and industrialization of commercial goods. In spite of such differences, projects in a broad sense—technical endeavors more specifically—have two very basic phases in common: a preproject phase and the project itself.

The preproject phases aim to identify possible projects, called project concepts, and to appraise them in terms of benefits for the organization that intends to employ them. When such phases are completed, it is up to the decision-makers to decide whether or not to go ahead. Approved and funded projects then are implemented in the second phase, i.e., the project phase.

Several characteristics make these two phases different. For instance, Christofol, Aoussat, and Duchamp (1993) mention that a preproject phase requires creativity, while a project phase must be managed with rigor. This is typically a situation that can be observed on real-world projects. For instance, a designer arrives in the office of an engineer with several plant layout proposals, and the engineer notices that basic quality assurance principles have not been respected, e.g., no title blocks on the drawings, no more drawing numbers, and missing dimensions. One can argue that more rigor could be detrimental to the creativity of the designer. These two concepts, creativity and rigor, can be opposed because creativity is generally associated with disorder, while rigor and order are almost synonymous. One can derive from this that these two phases should be carried out by different people with different skills, i.e., by product engineers or managers, by architects in preproject phases, and by project managers in project phases. Although this statement seems obvious, it is not always the case, especially when projects are complex. Some project failures can be explained because this dichotomy of skills has not been respected or considered.

The work loads and the duration of these two very basic phases also are different. Few people are generally involved in preproject phases over quite long and imprecise periods of time, while hundreds or thousands of people can be involved in project phases over the shortest possible time periods. This list of differences easily could be extended.

This breakdown into two very basic phases is theoretic in the sense that it intends to embrace all kinds of endeavors. Real-world projects obviously follow more pragmatic schemes. The project life-cycle approach proposed hereafter has been derived from several models commonly presented in the literature (Kerzner, 1994; Meredith & Mantel, 1995; Morris, 1988) and additional observations informally made by the authors from real-world practices. Three phases are considered: an initiation phase, followed by a feasibility phase, and a project implementation phase.

The inputs of the initiation phase, also called "concept phase" or "identification phase," are the keeping pace with technological innovations, economical trends, requests from customers, distributors or sales people, new products put on the market by competitors, or brainstorming processes. The initial phase aims to sort all this information to identify some project concepts. This does not mean that all the concepts made out of this phase are to be carried out. A rational attitude toward such initiation phases is to identify as many project concepts as possible and to eliminate the discordant ones through a preselection procedure with respect to the objectives of the organization. One can discuss whether or not this first phase belongs to the project in a broad meaning, but common sense leads the authors to think that the initiation phase is an endless process that continuously initiates new feasibility phases.

Selected project concepts—outputs of initiation phases—then are used as inputs for the second phase, the feasibility phase. This phase aims to analytically appraise project concepts in the context of the organization. This second phase can be understood as follows: on the one hand, there are the organization's needs, which in some cases can be expressed with the simple words of the strategic charter of the organization to which the feasibility is carried out; on the other hand, there are the capabilities and the know-how of the organization. With this information, the decision-makers should be able to decide whether or not to go ahead with each project concept proposed.

For technical projects, Clifton and Fyffe (1977) proposed to split this feasibility phase into subphases separated by intermediate decision points. The first subphase consists of a market feasibility analysis to confirm the viability of the project concept from a pure marketing point of view. If the results suggest that there is nothing to earn, the feasibility analysis of the project concept shall be stopped at that point. Otherwise, a technical feasibility analysis, or feasibility study, is to be carried out. Such an analysis serves to demonstrate that the project is technically feasible. It also provides the information required for estimating the costs associated with the implementation of such project concepts and for identifying, quantifying, and mitigating technical risks. Very often, environmental analyses are appended to technical feasibility studies to ensure that the project does not go against external constraints related to ecological issues, social profitability, laws, and applicable regulations. Based on the results of these technical feasibility analyses, another go or no-go decision is made to determine whether or not to initiate a financial feasibility analysis. Its aim is to establish if a project concept, once materialized, will generate profits for the organization. Basically, the outputs of such a feasibility analysis can be a single figure. If it is positive, one can go ahead, but if it is negative, the project concept can be abandoned and eliminated from the project concept portfolio.

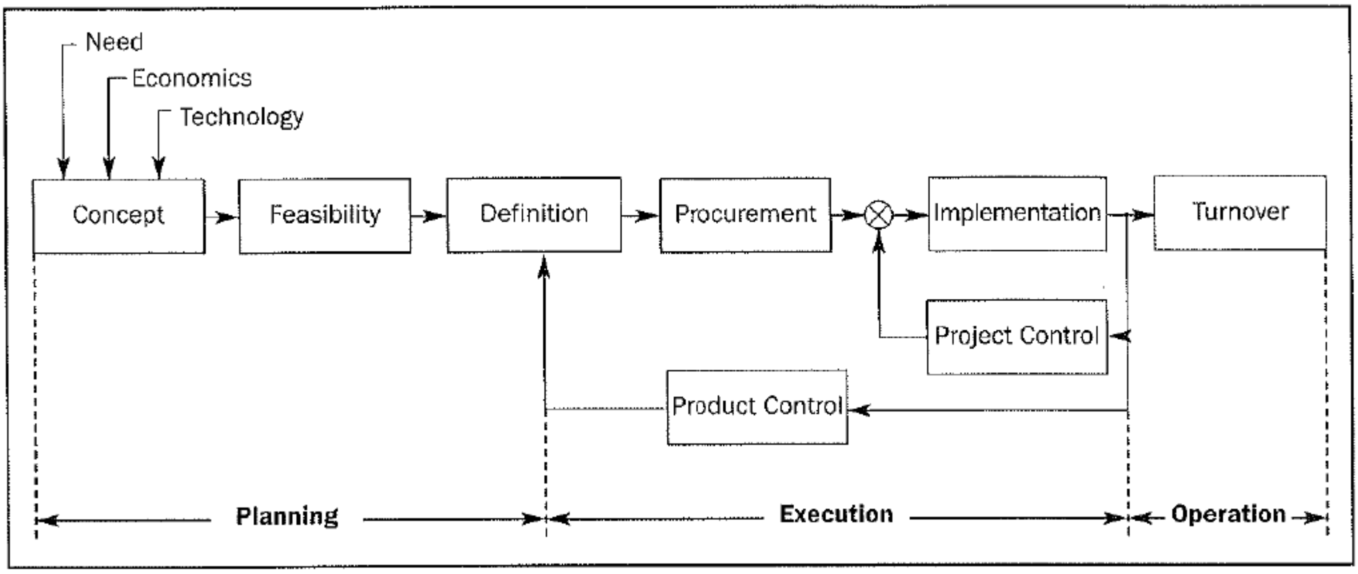

Figure 1. Control-Orientated Project Life-Cycle Model (Kelley, 1982)

It is reasonable to think that this figure shall be balanced with the internal (technical) and external (environmental) risks, the range and the accuracy of the information used, and the size and the complexity of the project proposed. The feasibility phase is known to be terminated when a decision-maker decides not to transform the project concept into a project. Morris (1988) recalled that at that point, in the case of a plant, the capacity is decided, the locations are chosen, the financing is arranged, the overall budget and schedule are agreed, and a preliminary organization is established.

The way a project implementation phase, also called a "materialization phase" or "realization phase," is conducted depends on the organizational context within which the project is implemented. It is initiated when the project has been appraised to be feasible and profitable. Once launched, nothing is supposed to interrupt the realization of the project. For technical projects presenting low complexity, the processes associated with this phase are quite straightforward. For speculative or complex projects, this phase can be split into a few subphases separated by intermediate decision points at the end of which the future owners and/or the stakeholders of the final deliverable can decide whether or not to continue the implementation of the project. For instance, in the petroleum industry it is quite common to have this materialization phase broken down into three subphases:

- A basic design phase carried out by an engineering company or an industrial architect, during which the documentation for tendering and contracting the physical construction or for procuring equipment is prepared. This phase is considered completed when engineering, procurement, and construction contracts are awarded, and when purchase orders for long-lead equipment are issued.
- A detailed design phase, immediately followed by a construction phase, carried out by one or more contractors during which the final deliverable (a plant, equipment, etc.) is made and commissioned;
- A post-project phase, turnover phase, or start-up phase during which the responsibility of the materialized deliverable is transferred from the engineers, the architects and/or the general contractors to the owners.

What makes the two design phases different is that, in a basic design phase, the final deliverable is seen as a set of functions to satisfy, while in the detailed design and construction phase, the final deliverable is handled as a breakdown of parts and pieces to procure or fabricate and to assemble.

The outputs of the basic design phase are similar to that of a feasibility study, except that they are more detailed; schedule and budget are reappraised based on an expanded description of the product and of the project. The milestone associated with the completion of this basic design stage is important, because the project can be stopped at that point if the conclusions of the feasibility analyses are not confirmed. Even if this breakdown into subphases slightly differs when transposed into other technical project contexts, e.g., automotive industry, defense, or big-science projects, the whole philosophy remains.

Control-Oriented Model

In the *Project Management Handbook* (op. cit.), Morris cites a project life-cycle approach attributed to Kelley (1982) (Figure 1). Kelley considers a project as a servomechanism with two levels of retroactivity: one using and acting on the product, i.e., the deliverable of the project, and another level using and acting on the project, i.e., the processes of making it deliverable. This model is interesting because it highlights one of the major duties of a project manager—checking that the product that is being made fulfills its specifications all along the implementation phase and that the project progresses satisfactorily to get the deliverable on time and on budget.

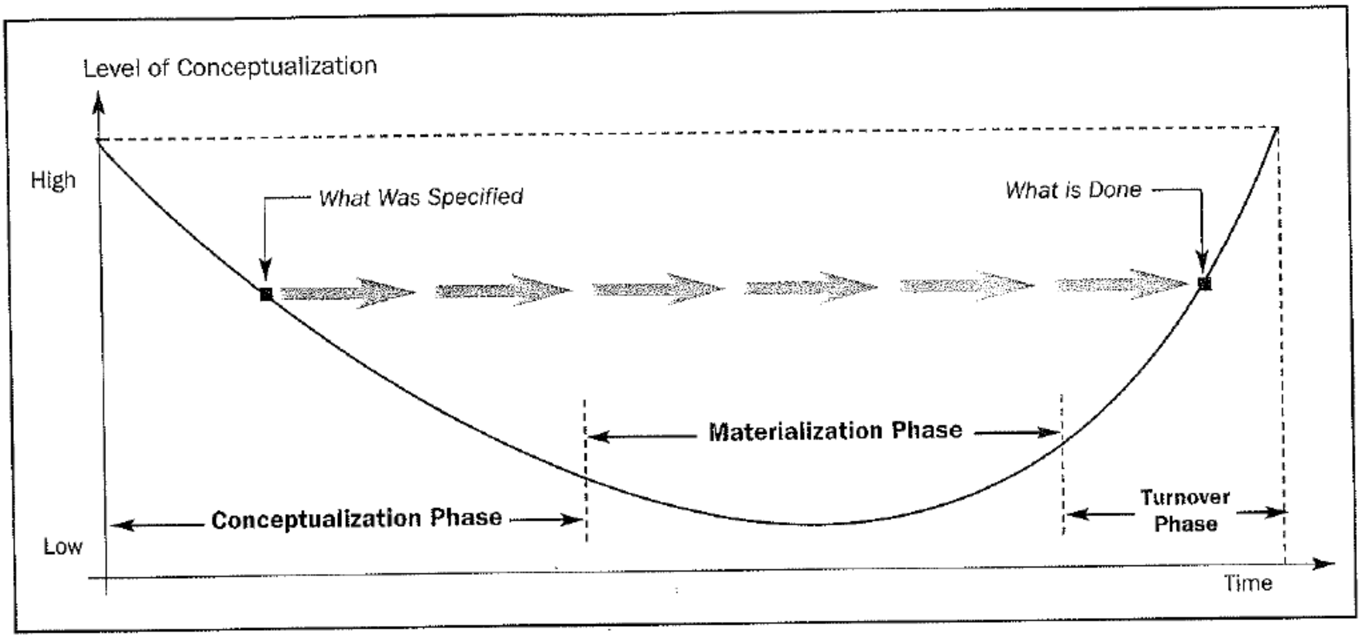

Figure 2. Project Life-Cycle Model Highlighting Project/Product Quality Matters

Quality-Oriented Model

The project life-cycle approach shown in Figure 2 cannot be attributed to one author in particular. It is widely used in project management classes, especially in those devoted to the management of IT projects. It can be easily transposed to the fields of technical projects. In it, the time runs from left to right—the level of conceptualization of the project at a given time is featured on an orthogonal axis. At the early stage of the project, this level is high. This is because the purpose of a basic design phase is to specify a set of functions that the final deliverable can satisfy. As the definition of the final product progresses, the level of conceptualization gets lower. The lowest level is reached when parts and pieces are being manufactured or when individual equipment is installed. This level grows when manufactured parts and pieces are assembled to form subassemblies, then assemblies, or when installed equipment is networked. The highest level of conceptualization is reached again when the project is terminated and the final deliverable is delivered.

Considering the evolution of the quantity of objects handled, this quantity follows an opposite scheme. At the early stage of the project, few functions are sufficient to describe the final product. With the project implementation progress, these few functions can be transformed in some physical systems and subsystems, which are made of assemblies and subassemblies; the leaves of that hierarchical scheme are finally made up of the elementary parts and pieces of the final deliverable. The project assembly breakdown structure allows for reconstruction of the final product for delivery.

According to a broadly known principle of quality management, "I say [and write] what I will do, she/he checks what I've said [and written], then I do what I've said, and I prove I've done it." The project life-cycle model shown in Figure 2 can be considered as quality-oriented, because it helps to understand the integration of this principle in the project management field. It has been said that the purpose of a basic design phase is to specify and endorse the final deliverable as a set of functions to satisfy; the project manager and his or her team are committed to making a product that fulfills these functions. The final acceptance of the deliverable should be conducted in such a way that the fulfillment of these functions can be demonstrated without ambiguity. For this to be objectively feasible, a final acceptance procedure should be written in accordance with the statement (the project charter) that the project manager and his or her team are committed. At lower levels, the same principle applies. A system should be commissioned according to the technical specification that describes it and so on, down to the manufacture, the assembly, and the installation. This system should include procedures describing the basic actions to be handled and control reports demonstrating that these procedures have been followed and that performance and quality aims have been reached.

This model is helpful to demonstrate that the documentation associated with a product/project shall not be issued erratically but shall follow rhythms of issuing to get and use at the right time documents describing the product/project at the right level of conceptualization.

Risk-Oriented Model

Risk management is another important issue associated with the project management body of knowledge. The model proposed by Lacoste (1999) (Figure 3) partially deals with this issue. This project life-cycle model is made of two very basic phases. The issues associated with the preproject phase remain the same: on the one hand, the requirements (what one needs) and, on the other hand, the know-how and the

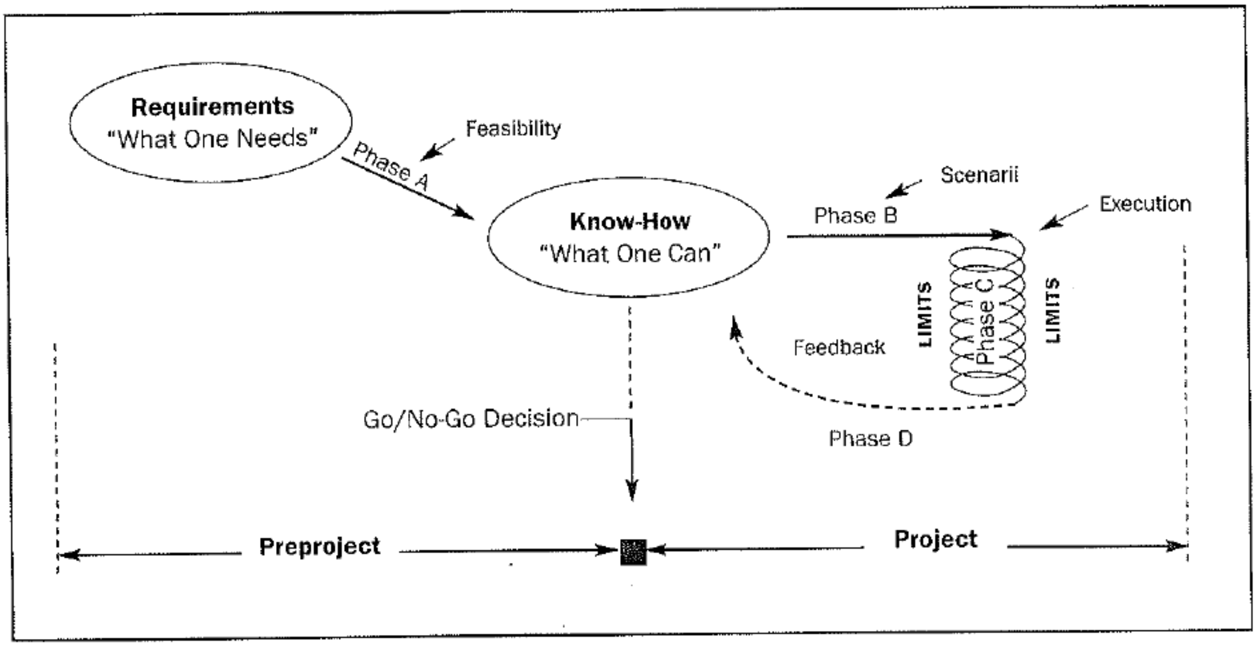

Figure 3. A Risk-Orientated Project Life-Cycle Model (Lacoste, 1999)

capabilities of the organization (what one can). For instance, a project concept could consist in developing a new product to fill up a market niche. The feasibility phase consists in verifying that the marketers' requirements are compatible or consistent with respect to the know-how of the organization.

Typically, the following studies are to be carried out: a market feasibility study to confirm the opportunity of developing the new product, a technical study to ensure the feasibility of the new product with respect to the means and the know-how of the organization (the new product can be feasible but out of reach for the organization), a financial study to check if the organization can financially afford the development of the new product, and environmental analyses to verify that this product does not go against external constraints.

The project phase itself is divided into three subphases: a planning phase (phase B in Figure 3), during which *scenarii* are elaborated, followed by an execution phase (phase C) during which the final deliverable is made, and a closeout phase (phase D), during which the experience acquired is recorded. This model differs from other project life-cycle proposals because a scenario phase is inserted between the feasibility phase—more precisely the decision to go ahead—and the implementation of the project.

This intermediate phase is concerned with three out of the four project risk management processes (as per the *PMBOK® Guide*): the identification of the risks (opportunities or threats) that are likely to affect the project's execution and the conformance to the specification of the final deliverable, its evaluation, and its mitigation. The main aim of the scenario phase is to plan risk responses. During the execution phase, it is the duty of the project manager to make use of the risk response planning elaborated in the scenario phase to steer the execution of the project within acceptable limits. All along the realization of this phase, it also is up to the project team to record the uncertain events that occur and the responses implemented to restrain in the case of threats or to enhance their outcomes for opportunities. This important information must feed the know-how repository of the organization.

Fractal Approach to Project Life Cycles

In the closing talk of a workshop devoted to project management seen from a sociologist point of view (In French, the neologism "projectique" was created to define this new field of knowledge; neologism could be translated into "projectics."), French academician Joël de Rosnay (1993) scrutinizes the evolution of project management from a linear motion—the emergence and development of project planning and scheduling techniques in the '50s and '60s—via a reticular countenance, the introduction of the management by projects in organizations in the '80s and '70s—to reach a fractal dimension.

A fractal approach to project life cycles (henceforth, fractal life cycle) can explain situations that are difficult to model otherwise. Especially those concerned with the overlapping or fuzziness of interfaces between phases, the spreading of responsibilities, and decisions that are made complicated when OBSs deal with the matrix organization of projects, and, more generally, the uncertainty and imprecision associated with the execution of any project. One of the dualities that distinguishes preproject and project phases can be heard from the mouths of many R&D project managers: "In a preproject phase, don't plan too much if you intend to remain creative. Plan your project correctly if you intend to deliver it in conformance with specification, on time and on budget." When looking to an endeavor with this in mind, it seems that some of it goes against universal project management practices. However, once gazed through a fractal lens, endeavors can be seen as quite homogeneous mixture of creativity and

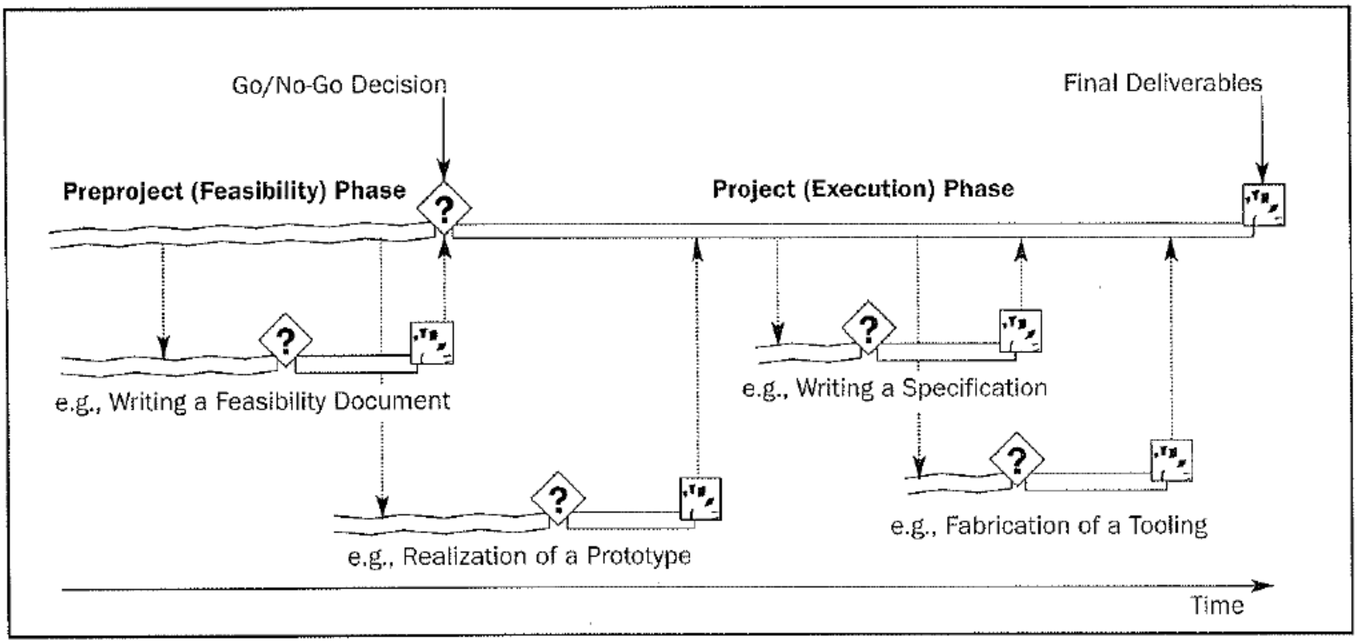

Figure 4. A Fractal Approach to Project Life Cycles

of strictness, all along any project life cycle from an early feasibility stage to the completion of a project.

For some examples, see Figure 4. Even if creative behaviors shall animate feasibility phases, in all the cases the deliverable of these phases are reports. These reports must be written and the actions of writing them are no more than projects. When the analysts in charge of carrying out such phases agreed on content, a more or less formal decision is made to go ahead. The quality of these feasibility analysis reports, including their issuing on time and on budget, depends on the level of elaboration of the plans.

The feasibility of a technical product/project is sometimes appraised with conclusive results made out of tests and measurements using prototypes. In such contexts, prototypes are subprojects of the feasibility study project. The issuing of a technical specification describing a prototype is a sub-subproject of the prototype subproject and so on. This way of reasoning also is applicable to the writing of technical specifications of systems and subsystems, to the performing of calculations or to the drawing of some plant layouts in a basic design phase. So is the design and fabrication of a special tooling in a construction phase or the treatment of nonconformities of equipment in a commissioning phase.

Using such a model, one can note that decisions are spread in all dimensions: hierarchical or temporal. At project level, the go/no-go decisions are made by stakeholders or the future owner of the final deliverable. At subproject level, it is up to the project manager to make decisions. At lower levels, decisions are made by project engineers or work package managers. The activities of a project manager do not only consist of making decisions at the project level, but, in many cases, he or she has a role of stakeholder, expecting that the delivery of a document, an assembly, or whatever he or she is able to request will conform with what he or she asked and delivered on time and on budget. This model also shows that project managers contribute (by their creativity) to processes that are upstream decision points in appraising pre-subproject opportunities.

Down to Project Management Practices

Before presenting what a project practitioner can gain in being aware of few project life-cycle models, the authors will discuss feelings regarding a common statement that can become a serious pitfall if not appraised carefully. Accurately forecasting the work to be done, the duration, and the resources needed to complete a project is not sufficient to ensure its performance. It is obvious that this contributes to the success of a project; but it is not enough. Issues such as possible rework, change control, product and project quality, or project risks also shall be taken into account when planning and scheduling the project.

Because project life cycles can be understood as "generic macro schedules," every schedule should be made according to project life cycles and, for technical projects in particular, to the four project life cycles presented earlier. However, commonly implemented planning and scheduling techniques are such—deterministic, nonrecursive (i.e., those that do not allow loops), nondiscursive (i.e., those that do not accept decision points)—that it is difficult to make schedules that can be consolidated at the life-cycle model levels. On the other hand, project life cycles—the ones presented in this paper, but also others—strongly use images as definitions. Even if the consolidation is difficult to make, the authors believe that having such images in mind when managing a project can contribute to the reality of the world.

The four project life-cycle models presented in this paper enforce four important aspects of the project management process: control, product and project quality, risks, and something the authors have called the fractal aspect of a project process. Before concluding, the authors present some key points a project practitioner can use to take into account these issues when planning and scheduling her or his project.

Rare are the project activity networks that take into account the control issue. A tendency in technical project management practices, however, is to multiply reviews, such as preliminary design reviews, critical design reviews, production readiness reviews, progress reviews, closeout reviews. It is obvious that the purpose of these reviews is, through the reviewers' recommendations, to make decisions. As a consequence of a review, an activity that was supposedly completed may be redone, an additional activity neither planned nor scheduled may be carried out, or simply to go ahead. It is up to the project managers to quantify these possible additional activities and to spread them as contingencies all along the project execution. This life-cycle model also highlights that the risks associated with the product (related to the product definition) and those associated with the project (related to the materialization of the product) shall be handled differently because their consequences concern different phases of the project.

As for state-of-the-art practices, project managers are strongly invited to break down their projects in tree-like structures. One can note that there exists a wide taxonomy of such structures:

- Project/product breakdown structure (PBS) aims to split the final deliverable of the project into systems, then subsystems, assemblies, subassemblies—down to elementary parts;
- Functional breakdown structure (FBS) is similar to the PBS, but it is oriented to the functions the final deliverable should satisfy;
- Assembly breakdown structures (ABSs) aim to detail the sequence of operations to get an object assembled or a plant constructed;
- Organizational breakdown structure (OBS) describes the organization of the project in terms of responsibility; the OBS is limited to decision-makers while the resource breakdown structure (RBS) takes into account all the resources involved in the project;
- Work breakdown structure (WBS) is a structured list of all the work packages and activities that have to be carried out to complete the project;
- Cost/contract breakdown structure (CBS) gives a breakdown of the project from a cost control and/or from a contract monitoring point of view.

The quality-oriented project life-cycle model is useful to the project practitioners because it helps them to understand the links that exist between all these structures and hence, to use the right ones at the right time over the project execution period. During the design and the commissioning phase of the project, i.e., at the early and late stages of the project, the FBS is very helpful to identify and list all the design documents (calculation notes, specifications, drawings) and the commissioning procedures to issue. The ABSs are mostly used during the materialization of the project. They are prepared as the design progresses. The WBS and the OBS/RBS, which are the inputs to the schedule, are made and updated according to the PBS, FBS, and ABSs. If all these structures are correctly interlocked, and the quality-oriented project life cycle model is helpful for that purpose, the quality of the project plans and schedules is increased.

The project risk management is one of the knowledge areas of the *PMBOK® Guide*. The risk-oriented project life-cycle model presented is helpful to understand how the six phases of the risk management process are articulated. Phase A (at a macro level) and phase B (at a micro level) aim to prepare *scenarii*, i.e., to identify and quantify risks, develop plans to respond to these risks, and set up limits not to overstep. Phase C then is conducted in such a way that the limits previously defined are not exceeded. Last but not least, phase D shows that a continuous feedback mechanism is fundamental to fill up the know-how repository of the organization. The risk-oriented project life-cycle model enforces the fact that planning and scheduling on the one hand and risk estimating and monitoring on the other hand are deeply interlocked all along the project.

This approach seals the breakdown of a project into subprojects and so on down to "elementary projects." Then all these projects, whatever their level of complexity, comply with a very simple life-cycle model made of two phases: a preproject (feasibility) phase and a project (execution) phase separated by a go/no-go decision point.

This fractal view very often is implemented on technical projects, especially on large-scale industrial projects. Practically, a time management system is made of two or more levels. Three levels can be beneficial for understanding what follows.

The first level of such a planning and scheduling system deals with strategic issues, and the master schedule aims to reflect the strategy of the project. This schedule is issued prior to the go decision. It covers the long term, i.e., the whole duration of the project from the go decision to the closeout. It is the tool the project manager uses to communicate with the external world.

The intermediate level of planning and scheduling deals with tactic issues. For instance, in the case of a large-scale project it is difficult for someone to have a precise and detailed view of the installation and commissioning phases when the project is just launched. Hence, this intermediate level is made of several overlapped coordination schedules covering the midterm. The first coordination schedule to be issued covers the design phase of the project. It is followed by a procurement coordination schedule, a construction and installation coordination schedule, and finally a commissioning coordination schedule. This intermediate level of planning and scheduling is made of work packages that are roughly defined at the early stage of the project and which become more precisely detailed as the project progresses. The way the work packages are consolidated at the top level is obviously a prerequisite to the issue of the corresponding coordination schedule.

Still within the scheme, the bottom level of planning and scheduling deals with operational issues. Generally, detailed schedules cover short-term periods, from a few weeks to a few months; they are made of the elementary activities. As for work packages, the way elementary activities are consolidated at the corresponding coordination level constitutes a prerequisite to the issue of the detailed schedule. Many project practitioners are familiar with such practices. In some domains, for instance in the offshore oil platform or nuclear waste reprocessing plant construction industries, four or five levels of schedules are common practices.

Real-world schedules, whatever their level, seldom do take "preproject activities" into account, if ever. One can argue that "creativity" is something difficult to estimate and, therefore, to schedule. Nevertheless, the time spent in dealing with these preproject activities must be considered in the project overall work load. The consequence is that project work breakdown structure viewed through this fractal lens is much more exhaustive and closer to reality. The project shall benefit from that.

Conclusions

Projects are characterized by their specificity: an endeavor that has a start and a finish, a precise and unique aim that is carried out by a team set up for the purpose of the project. The purpose of a project life cycle is to find something common to all projects among all these differences. Project life-cycle models, whatever they are, are located on a continuum going from the simplest project life cycle, which is made of two very basic phases and applicable to all types of projects, to project schedules that are precise and detailed but only applicable to one specific project. Because project life cycles are models, their purpose is to explain the real world in a simpler and understandable way. Because the world of projects does not consist of a very small number of variables, it is difficult to imagine—and perhaps impossible to make—a model that could integrate all the variables that make all projects specific. In order to understand the projects they are involved in, project managers and team members must share a common view of their projects and especially on the way a project progresses. It is the purpose of project life-cycle models to illustrate simply the "progress philosophy" of the projects to promote a better understanding and a better communication within the projects.

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