BALANCING CONTROL AND FLEXIBILITY IN THE MANAGEMENT OF R&D PROJECTS

Roberto Cimino
Enitecnologie S.p.A.
Via Maritano 26,
20097 ITALY

1. Introduction

Technology innovation is increasingly becoming a key lever of competitive advantage for companies operating in very diverse business sectors.
Taking for instance into account, as a reliable indicator of the pace of technology innovation, the number of patent applications filed every year in the U.S.A., it is striking to notice how this number has more than doubled in twenty years, from 100,000 applications filed in 1980 to over 250,000 at the end of 1999.
A strong position in a given technology sector, measured often by the number of granted patents, is today considered to secure the best and most reliable barrier to entry into business, in a world where capital is cheap and labor mobile (The Economist, 2000).
Innovation not only provides competitive advantage to technology-savvy companies, it can also lead to the emergence of so called "disruptive technologies", able to displace companies not swift enough to innovate from their leadership market position (Christensen, 1997).
Mastering the process which, often painfully, pushes new ideas from the laboratory to the market is therefore paramount for companies willing to compete, and perhaps survive, in today's world.
The project organization provides, in principle, the best and most efficient way to plan, control, and finally deliver the expected results, within a given schedule and budget: by breaking down the project objective into well defined work packages, it is possible to appraise the resources (and therefore the cost), the overall time needed and, most important, to organize the work so that it can be controlled to make sure that its alignment to project objectives is guaranteed.

2. The projects of technology development

Project management is a consolidated technique when the bases of the project itself are quite well defined, as for the construction of a refinery or a petrochemical complex in a given site: in such cases the specifications of the deliverable can be identified in advance through negotiations with the client, since the technologies involved are usually well known, and the uniqueness of the endeavor basically consists in a work of adaptation of known factors to the customer's requirement, taking into consideration the constraints of the site.
Complex development projects are quite different: they have often to start from the phase of idea conception, where uncertainty is very high, and move downstream the innovation funnel by building highly interrelated work packages, whose relations and sequence is much more difficult to specify in advance (Sőderlund, 2002).

If we take into consideration a typical project for the development of a process technology, this can ideally be broken down into two main phases:

- Laboratory Research, characterized by uncertainty in time/cost/results and subject to frequent changes as a function of the results actually found;
- Development, where the technical results obtained in the research phase have to be tested at a proper scale, often in a pilot/demo plant, prior to their transfer to the market;

While the latter phase usually allows a good definition and organization of activities, the former is much more difficult to plan and control, due to uncertainty and frequent changes.

The Research phase obviously calls for room to creativity, which alone can sparkle effective innovation: conventional planning and control approaches not only are difficult to apply but probably not even adequate for such a purpose.

In addition to this intrinsic complexity, increasing management's pressure to reduce the time needed to bring technologies to industrial exploitation, forces project managers to adopt more and more often "fast tracking" or "concurrent engineering" strategies, which basically consist in anticipating activities as much as possible, even though, from a conceptual standpoint, they should start only when preceding activities have delivered all the necessary information: such an approach leads to even more complex interrelationships, which can now be found not only between tasks of the same phase (f.i. laboratory research), but also between the two phases themselves, since a sequential logic cannot be used any longer in the planning and control of the overall project.

Scholars in project management often distinguish between projects based on "analyzable" activities / work processes and those based on "systemic" ones: the former are characterized by activities that can be quite well specified in advance and whose degree of interrelationship is not high, the latter display highly interrelated work packages (Lindkvist, 1998).

Due to the uncertain feature of research as well as to the need of increasingly compressing project schedules, today's research and development projects certainly have to be regarded as systemic projects, and call therefore for a systemic project management approach, able to identify all the technical relations and interdependences between work packages, to provide an efficient toolkit for project control and, finally, to strike a balance between the two conflicting requirements of allowing room to creativity, especially in the early project phases, and planning/controlling costs and schedule.

3. Project plan and control in R&D projects

An important part of the development projects in the petrochemical and energy field deals with the transfer of process technologies to the industrial stage.

Such projects often target the definition and development of new catalytic/separation processes, from the laboratory scale, through intermediate validation on a pilot/demo plant, to the final industrial transfer: the endeavor usually involves a vast array of disciplines, spans five or more years and entails a substantial amount of money.

In figure 1 the three main conceptual phases for such a type of projects are reported, with reference to a case where the development of a new catalyst and an innovative reactor technology are the technical pillars of the projects.

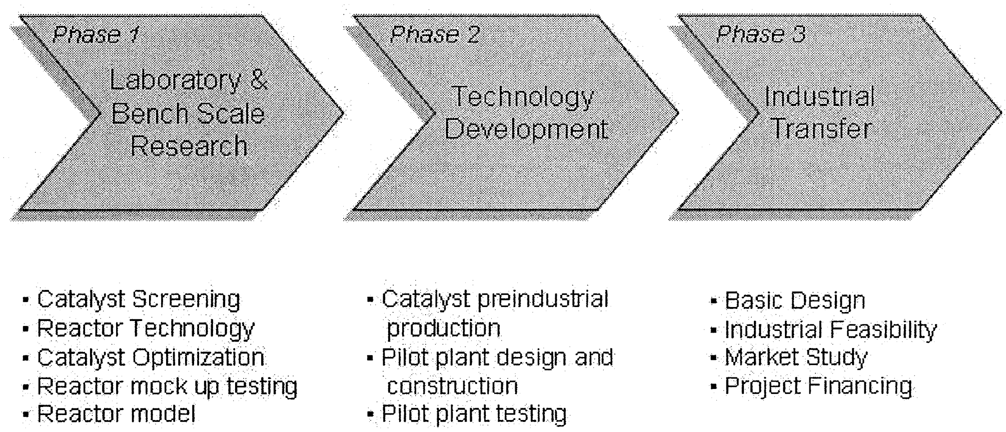

Figure 1: The phases of a typical program for the development of a process technology

Since the projects' schedule usually stretches for five or more years, it is convenient to break it down into two major phases, prior to the industrial transfer one: Laboratory & Bench Scale Research (Phase 1) and Technology Development (Phase 2).

Phase 1 is designed to deliver the pillars of the technology (in the specific case, a performing catalyst and the design of the reactor), which have to be validated through testing on a pilot unit in Phase 2.

Often, between the two phases, a major check point has to be foreseen, in order to decide whether there are or not the conditions to proceed to phase 2.

Phase 1 usually starts from a preliminary research and, in some cases, from the idea itself: it is therefore the section of the project more risky, uncertain and difficult to plan and control.

First of all, the specifications of the target of Phase 1 have to be defined, as detailed as possible.

Sometimes, such a definition is overlooked or is not transferred in an unambiguous way by the top management: the success of any project, however, depends on whether or not target is reached, and making sure that the project manager is steering the project in alignment with management's expectations, is crucial.

A project charter for phase 1 has therefore to be prepared, based if necessary on project manager's understanding, reporting the specifications of the target, as well as the planning details: such a charter should be circulated up to the top management level.

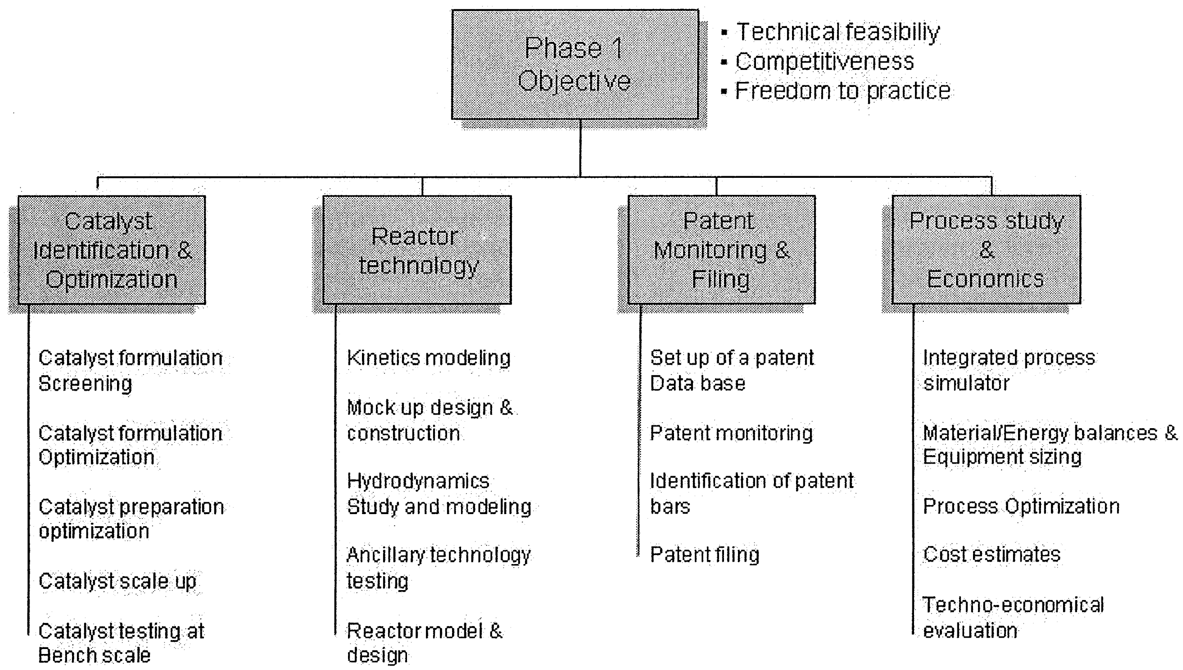

Figure 2: The work breakdown structure of program's phase 1

In the case reported in figure 2, the target specifications included Technical feasibility (detailed with target performances of catalyst and reactor technology), Competitiveness (on the basis of a preliminary techno-economical evaluation and benchmark with competing technologies), Freedom to practice (no major third parties' patent bars).
Starting from the objective definition, Work Breakdown Structure (WBS) approach can be used to break down the phase 1 objective: one of the most important reasons to adopt such an approach is that it forces, if well used by involving the project team, to consider all the work packages needed to accomplish the objective and therefore, minimize the risk, in the planning phase, of leaving out some of the activities (Archibald, 1976).
As shown in figure 2, Technical feasibility breaks down in two main work packages ("Catalyst Identification & Optimization" and "Reactor Technology"), Freedom to practice into the package "Patent Monitoring and filing", and Competitiveness into "Process studies and Economics".
The main work packages (four, in this case), can be further detailed, to identify, as the theory teaches, smaller and better manageable tasks, that can be more easily assigned to a task manager.

However, even though the aforementioned approach (Project Charter Definition and WBS) is a necessary step, for a phase so uncertain and complex cannot be considered enough: as a matter of fact, these two techniques fail to identify the interrelationships between the activities, not helping the project manager and its team to realize all the complex network of information flow that has to be guaranteed during this project section's life cycle.

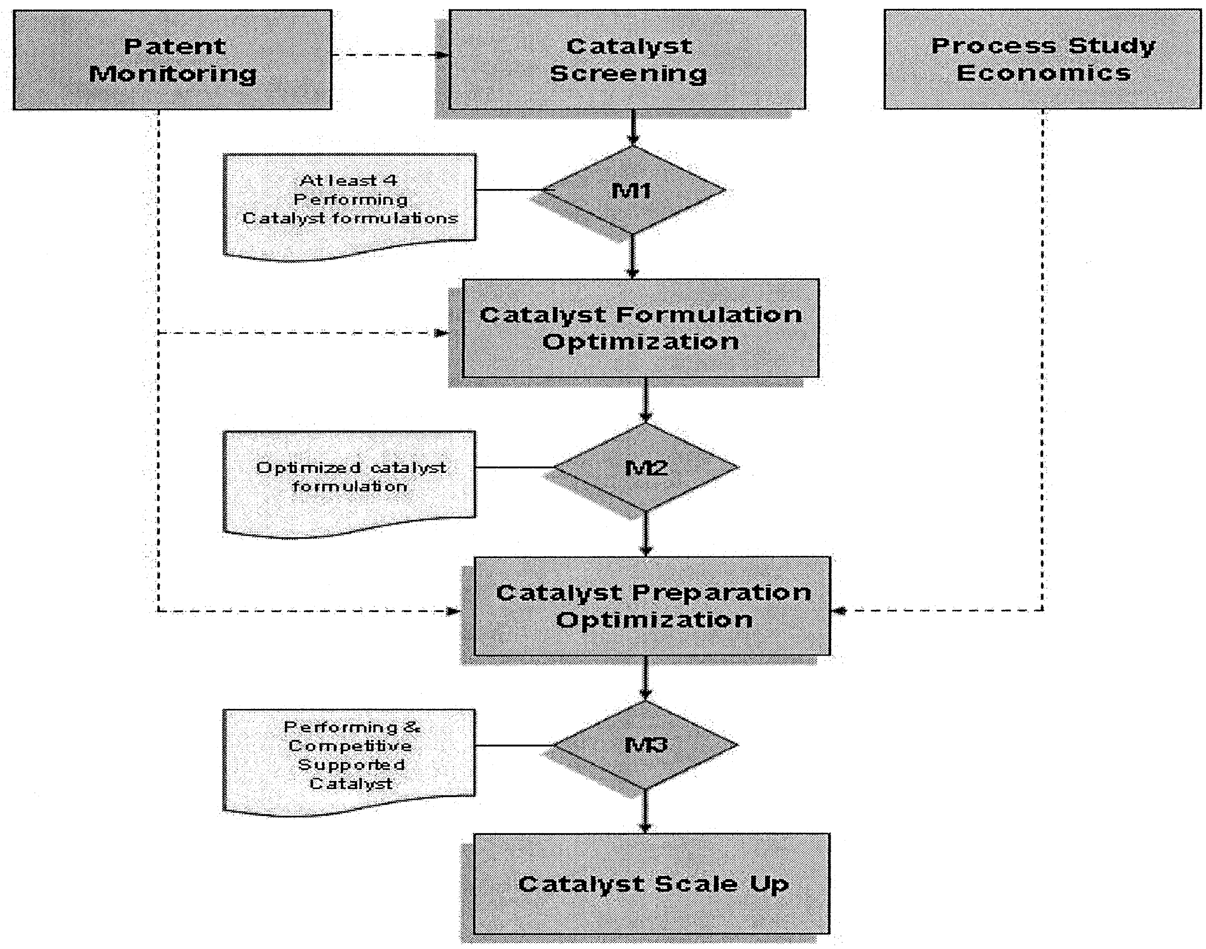

Figure 3: Flow Diagram of activities for the work package "Catalyst Identification & Optimization"

To this end, the technique of developing Flow Diagrams (Pearson, 1990) of activities is particularly recommended, since it can identify:

- the interrelationships between tasks;
- the proper milestones to be reached;
- the feeback loops between activities.

As an example, in figure 3, such a flow diagram is shown for the work package "Catalyst Identification and Optimization".

Working with the project team, the project manager has identified four main tasks for this work package (catalyst screening, catalyst formulation optimization, catalyst preparation optimization and catalyst scale up) and three milestones.
In addition, the main relations with the other work packages are shown: "Patent Monitoring", through the set up of a continuously updated database, has to screen , among the formulations identified by researchers, the ones which are not barred by third parties existing rights, whereas "Process Study and Economics" has to deliver the criteria to accept catalyst performances which, in perspective , can be competitive with respect to existing technologies.
Such a Flow Diagram shows also how concurrent engineering approach has to be used: as a matter of fact, a process study and economical evaluation has to be carried out, even though on a preliminary basis, before the pillars of the technology are defined.
Indeed, such a technoeconomical evaluation is used as a screening tool for one of the pillars itself, the catalyst: such an approach calls obviously for the use of assumptions, which have to be refined and validated in the further steps of the project.

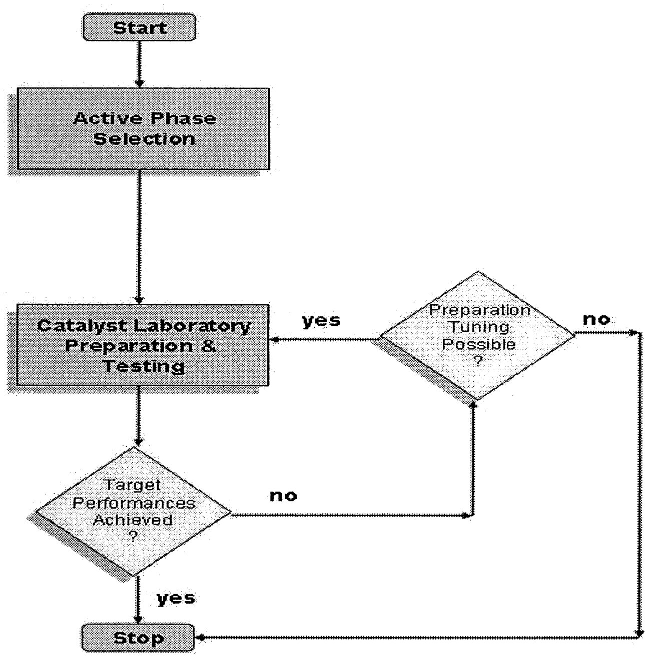

Figure 4: Feedback Loop of the task "Catalyst Screening"

The detail of each of the tasks identified through Flow Diagram approach, can be worked out by using "Feedback Loops Diagrams", which are also useful to estimate both the resources and the time needed to accomplish the task.
In figure 4, such a Feedback Loop is reported detailing the task "Catalyst Screening" shown as the first activity of the diagram of Figure 2.
As it can be seen, the task starts with the selection of active phases and goes on with Catalyst Laboratory Preparation (on a reference support) and Testing (in microreactors): if Target Performances are met, the first formulation has been found, if not, preparation tuning is considered and, if unsuccessful, the activity stops.

By carefully blending Flow Diagrams for detailing the main Work Packages with Feedback Loop Diagrams, the identification of all the main interrelationships between activities can be guaranteed and a reasonably good estimate of resources /time needed made.
Such an approach is useful to the project manager, who can control whether the flow of information is in tune with what has been planned, as well as to the task managers.

An additional example of the use of Flow Diagrams is shown in figure 5, where the interrelationships between tasks of the work package "Reactor Technology" are shown.
Again, two other work packages ("Patent Monitoring" and "Catalyst Identification & Optimization") do contribute with flow of information to the decision which have to be made within the package "Reactor".

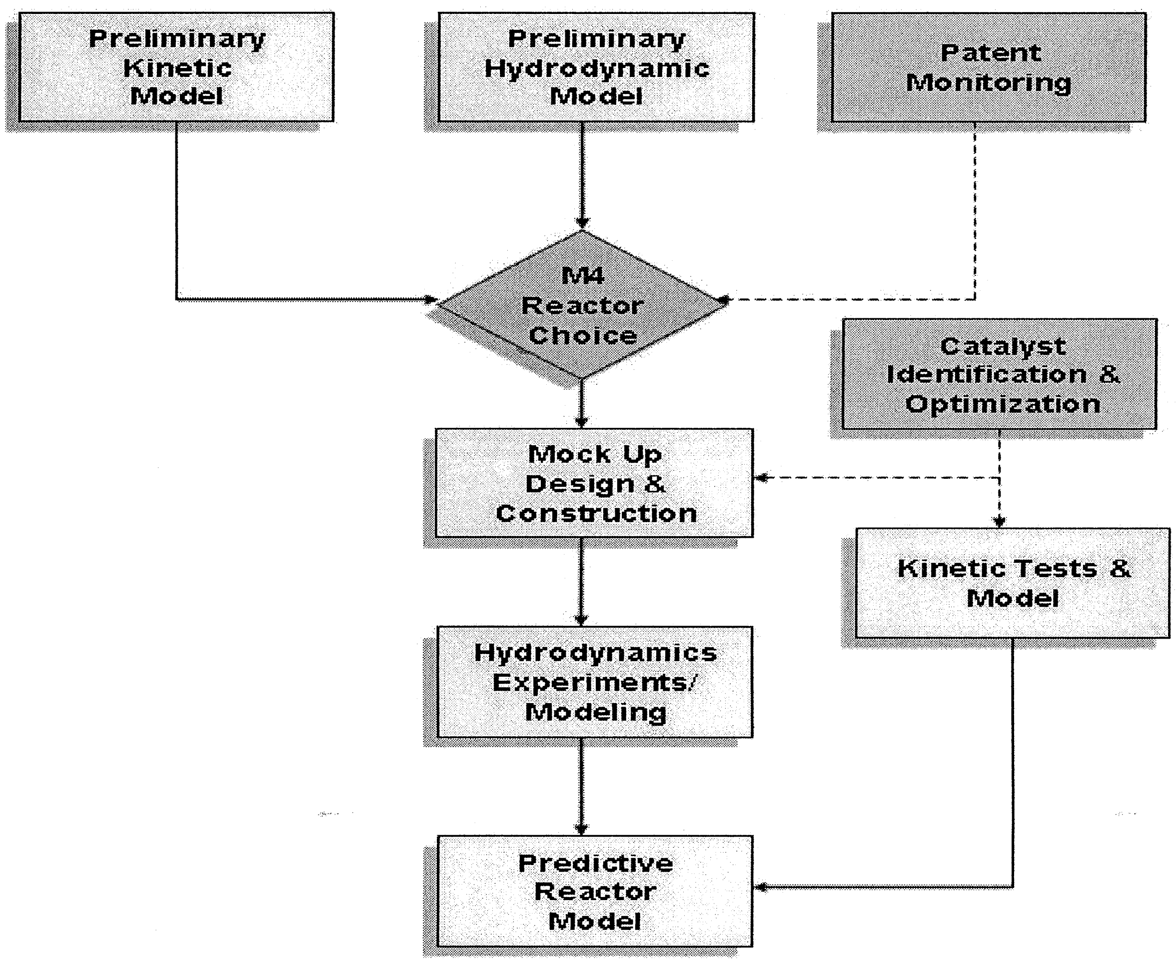

Figure 5: Flow Diagram for the work package "Reactor Technology"

Once the Research Phase is completed, the project has to proceed to phase 2, whose overall objective is to develop the technology through its validation on a pilot scale.

Again, a Project Charter Definition is the necessary first step to reach a common understanding and agreement among project stakeholders on yardstick against which success will be measured, as well as to start to work on phase 2 decomposition into work packages and tasks.
In figure 6, the Work Breakdown Structure of the Development Phase is shown, together with the specifications of its target :

- validation of Process Book;
- Production of products at specification on the pilot;
- Validation of material of construction;
- Validation of catalyst produced at preindustrial scale

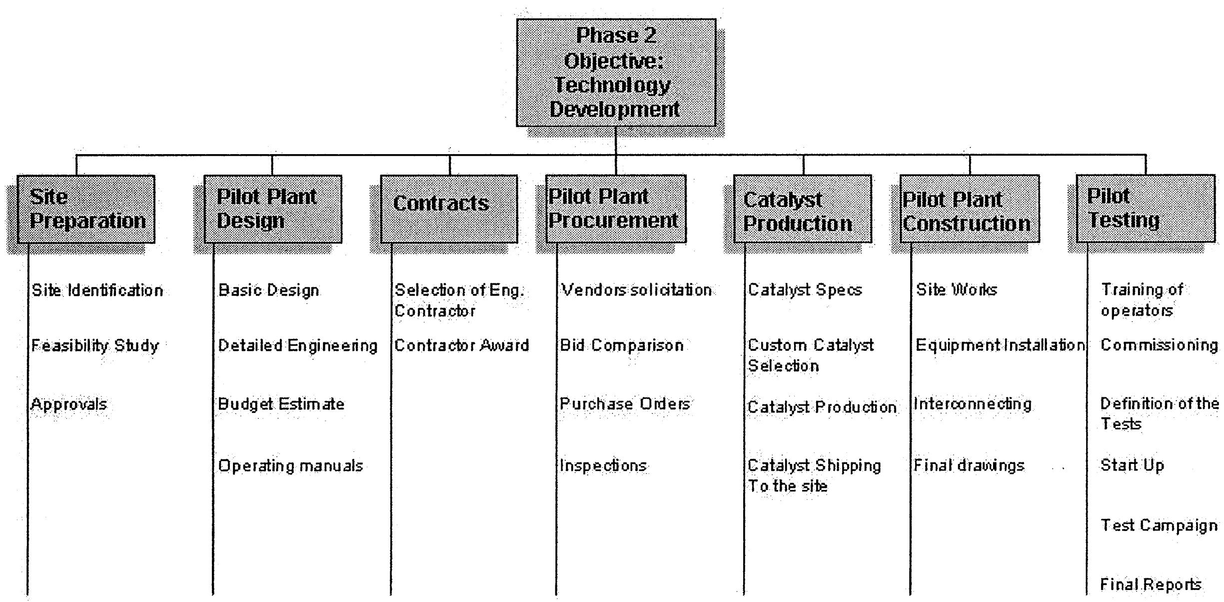

Figure 6: The work breakdown structure of program's phase 2

Again, WBS is mainly used as a scope management tool, to make sure that all the activities needed have been included , budgeted and scheduled.
The work packages include:

- Site preparation, since the pilot, in the case of the project considered, needs infrastructures which are available only in an industrial site;
- Pilot plant design, carried out on the basis of the specifications of the pillars of the technology (catalyst, reactor) defined during Phase 1;

- Contracts, since the strategy for pilot construction is outsourcing the work to an engineering company;
- Pilot Plant Procurement;
- Catalyst Production, since a key aspect of the validation is related to the ability of reproduce catalyst performances when this is produced at a preindustrial scale starting from the receipt defined at laboratory and bench scale;
- Pilot Construction;
- Pilot Testing

The work packages of such a phase are much less interrelated than the ones considered during phase 1, since the overall phase resembles much closer the structure and organization of a more conventional construction project.
Complexity, however, cannot be avoided completely, since the basis of design of the plant are unproven (this is precisely the purpose of the pilot unit, prove the assumptions) and, in addition, concurrent engineering forces to organize tasks in a parallel mode.

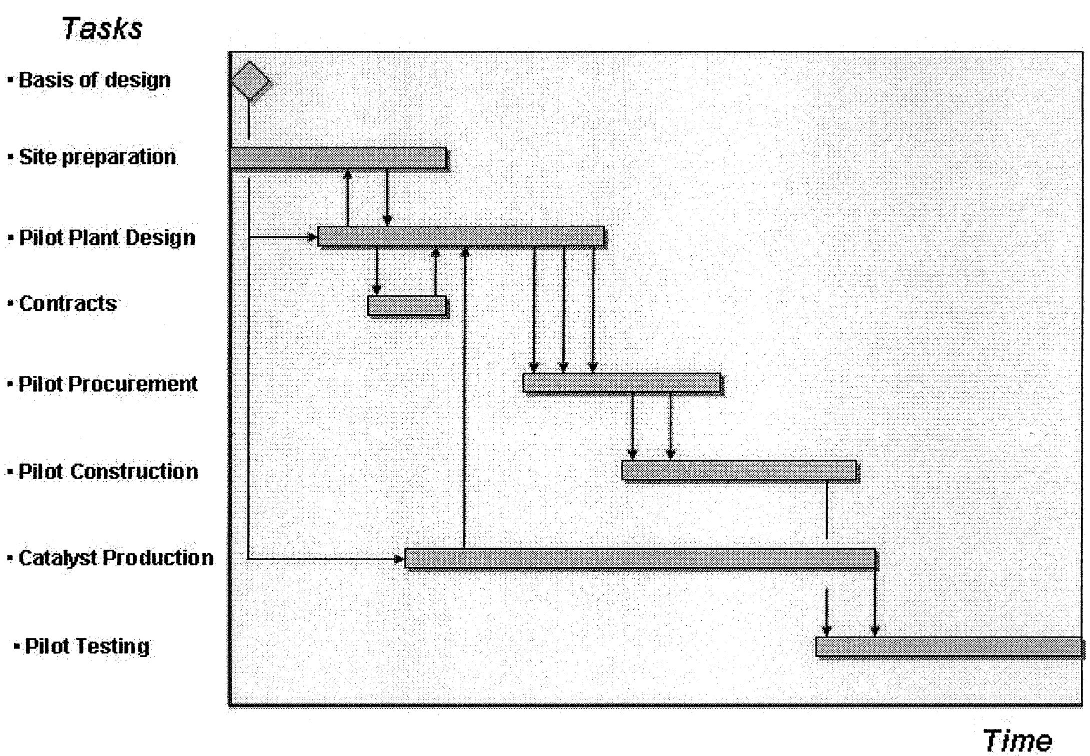

Figure 7 : Interrelationships between tasks

In figure 7, the Gantt Diagram of phase 2, built from the WBS of figure 8, is shown: tasks start prior to the completion of the activities which precedes them from a logical standpoint, because of schedule compression.
This generates an interrelationship among tasks which forces to identify the flow of information needed to properly manage the project.
The typical example that can be mentioned is the fast tracking approach followed for the planning of the tasks "Pilot Plant Design", "Pilot Procurement" , and "Pilot Construction",

which should in principle follow in series, but, as a matter of fact, overlaps virtually in all construction projects.
Such a model is often referred to as "fountain model", as opposed to "waterfall" or stagewise model: the more tasks overlap, the more there will be interdependence between them and the more flow of exchanging information will be generated, increasing project complexity but shortening, as much as possible, its schedule.

4. Conclusions

Research and development projects have become increasingly complex as a consequence of the need to compress projects overall schedules.
In addition, especially during the Research Phase, interdependence among project tasks is very high and the usual analytical approach in planning and control do not apply any longer.
A systemic approach is definitely needed and, to this end, a blend of different tools and techniques can be recommended: integrating analytical approach (WBS) with Flow Diagrams and Feedback Loops allows the representation of the interdependence among tasks, enables a more accurate estimate of resources needed and schedule, represents a good communication tool between project manager, task manager and the team.
The phase of technology development displays features which are more analyzable: interdependence however should not be overlooked, since it is generated both from the still unproven basis of design and to schedule compression / concurrent engineering approach.
Successful management of R&D complex projects, in today' s demanding and competing business environment mainly calls for project manager's ability to take into account complexity and interdependence both in the planning and control phase.

Bibliography

- Archibald, Russel D., "Managing High-Technology Programs and Projects", J. Wiley and Sons (1976);
- Christensen, Clayton M., "The Innovator's Dilemma", Harper Business (1997);
- Lindkvist,L., Sőderlund ,J. and Tell, F., "Managing product development projects-on the significance of fountains and deadlines", Organization Studies, 19, 6, pp. 931-951 (1998);
- The Economist, "The knowledge monopolies", p. 85-89, April 8th, 2000;
- Pearson, Alan W., "Planning and Control in Research and Development", OMEGA J. of Mgmt Sci., vol. 18, no. 6, pp. 573-581, (1990);
- Sőderlund, Jonas, "Managing complex development projects: arenas, knowledge processes and time", R&D Management vol. 32, no. 5, pp. 419-430, (2002).