The integration of new technologies: the stakes of knowledge

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Abstract: In order to remain competitive in an increasingly competitive international context, French companies are forced to follow one or more of various possible routes: relocating some of the activities, optimizing the design and / or production process, or innovate technologically. When they choose to develop new technologies, it is advisable to seek outside expertise in different areas. Thus they must exchange and create knowledge in partnership with other companies. But in order to control and integrate this future technology, we support that the acquisition and the capitalization of the technical training, during the process of innovation, are of primary importance. This article demonstrates that the construction of this knowledge base can be achieved only by formalizing close and rigorous collaboration. To do this, we propose a model of the collaborative process, meant for the leaders of innovative projects to support design.

Keywords: technological innovation; collaboration; conception; technical knowledge; SME; laser technics.

Reference to this paper should be made as follows: Roulet, N., Dubois, P., Aoussat, A. and Le Coq, M. (2008) 'The integration of new technologies: the stakes of knowledge', *Int. J. Product Development*, Vol. 00, Nos. 0/0, pp.000–000.

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1 Introduction

Today in the face of increasing international competition, small and medium-sized French companies in the field of precision mechanics, must optimize their Cost-Quality-Time triangle if they are to keep their market shares and acquire new ones. The action that seems most obvious to a French company wishing to evolve in a global marketplace is the relocation of part of its operations. However, this solution (proximity to customers and lower payroll) is very complicated because it requires the transfer of resources and know-how, adaptation to the culture of the host nation, respect of basic local administrative tenets …This offshoring process, though sometimes unavoidable is very long and very expensive. Companies have an opportunity, in conjunction with this type of project, to operate a strategic lever which affects their competitiveness just as much: the development and integration of new technologies.

However technological innovation is neither simple nor innate (Boly, 2004; Lorino, 1995). It is a process which relies on multidisciplinary collaboration and specifically the encounter of various technical skills. This encourages companies to innovate in partnership with research centers and corporate experts (Cadix and Pointet, 2002; Iansiti, 1998; Mercier, 1998). But to ensure the sustainability of their operations, manufacturers must be able to control their innovation at the end of their co-development.

In this article, we show the strategic impact that the industrial world ascribes nowadays to innovation. This phenomenon can have many meanings. Many authors have attempted to describe it, both in the economic environment and in the scientific world. We will take position on these various definitions and focus our work on the concept of technological innovation. In our view, this is the parameter which remains the greatest influence on the competitiveness of a company. Any technology is based on scientific and technical knowledge, on related knowledge, on resources and on know-how. But we will show that the foundation lies in the technical knowledge. Without the latter, it is impossible to control and integrate technological innovation. Starting from this premise, we advocate the conditions that may stabilize the technology under co-development within the company. One of these is the formalisation of a close and rigorous collaboration with partners. It fosters better communication, and optimizes exchanges (of information, data and knowledge) and especially as well as design activities. We propose, as part of this article, a model of collaborative process for project managers. The originality of this model will allow them to acquire the knowledge and techniques created and capitalized during the project. We will present the results of its deployment applied to the design of a process for laser cladding cutting tools (Roulet, 2006). This collaborative process is one of the foundations contributing to the success of innovation. Without these rigorous exchanges integration and the outlook for any new technology in the enterprise will not be feasible.

2 Innovate: the best way to compete

Since the 80's, all company directors have faced the problems of reducing product life cycles, reducing costs and delays, accessing specific markets, differentiating products and processes relative to direct and indirect competition, etc. The adaptation of businesses to new technologies and new practices has become an increasingly necessity present. Ever faster technical developments lead to questioning products, services or production processes. The company is faced with constant change, including in its structure and management methods. "In many cases, a refusal or even a delay in adapting will lead inexorably to the company's decline" (Mabile, 2002). Faced with this characteristic, one can no longer consider innovation simply as awarding of a new criterion to a product, process, service or organization, but as a true corporate strategy aiming to remain present on the markets (Hobday and al. 2000).

In 1997, results of a survey carried out by the French ministry of the economy showed that the primary motivation for innovation was growth and the conquest of new markets. In a more recent study, the same organization claims that this motivation is still primary for 80% of innovative businesses (SESSI, 2002). What was a tendency at the end of the 90's, has become the sole purpose of launching innovative projects in companies. It has been amply demonstrated, through literature, that there is a direct link between innovation and increasing competitiveness of a business (Bienaymé 1994; Tang, 2006; Ribault et al., 1991). As highlighted by a poll directed to more than 500 companies, innovative actions are on average well rewarded (Little, 1999). The value created by the company in a decade is substantial. It is expressed by the measure of shareholder value (shareholders' capital gains dividend +), which ranges between 5% and 20% depending on the level of involvement of innovation in the company. It should be noted that highly innovative enterprises have created 12% more shareholder value than businesses for whom innovation is not a priority. We can conclude that the benefits generated by an innovation management are consistent.

Innovation is a process now recognized as the main driver for a firm's competitiveness. The relevance of a choice to launch an innovative project or establish a genuine innovation management no longer arises. This route is the only way to survive (maintain a market share) and expand (conquer new markets), in a context of international competition.

3 Technological innovation and technical knowledge

The term of innovation (through the economic interest it fosters) became a genuine vector of communication, synonymous with change and with advancement for a company. We will define the concept of innovation as well as the various meanings one can allocate to it in the literature. But we will focus more particularly on the concept of technological innovation which is at the base of our research. We will point out the bases of technology and highlight the paramount role of technical knowledge.

3.1 Technological innovation: definition and position

"Innovation is the first commercial use of a product, process or service, which had never been used before" (Schumpeter, 1939). Schumpeter, a precursor of the concept, defines innovation as the result of the enhancement of the economic and social value of invention. To become an innovation, a new idea must find an application (internal or external) in a market (Cooper, 1983; Rothwell and Gardiner, 1988; Sutton, 2001). Through these initial views on innovation, we can distinguish two schools of thinking:

- Authors who view innovation as a result. The product, the service or the process put on the market are an innovation (Legardeur, 2001; Ribault et al., 1991).
- Authors who view innovation as the process allowing this result to be reached, i.e. the various actions which will transform the invention into an economic and social success (Kanter, 1983; Kline and Rosenberg, 1986; Utterback and Abernathy 1975).

We agree with the writings of Boly who describes innovation as a polysemous concept. Thus we find in the literature definitions that correspond to "the vision of the economist, the operative vision, the vision of the cognitive scientist, the systemic vision, the sociologist's vision, the biologist's vision …" (Boly, 2004). Each discipline creates its own formalisation of the concept of innovation. This term, formerly used to describe new processes, new products or new organizations, is becoming more common in many industries. It now encompasses very different forms, in all the fields of corporate activity: marketing, finance, organizations, production processes, product design, technology… (Mabile, 2002). And it goes even beyond the world of business to settle in areas closer to the general public (we hear of political innovation, social innovation or cultural innovation).

Among these multiple types, we focus in the rest of this article solely on the concept of technological innovation (related to products and / or processes). We position ourselves in relation to the definition given by the Oslo manual (OECD 1997) that distinguishes, in technological innovation, product innovation from the innovation process:

- Product innovation is "the market introduction of a product (good or service) that is new or substantially modified in the light of its basic features, technical specifications, incorporated software or any other components as well as intangible components as well as intended use or ease of use " (OECD, 1997)

- Process innovation is "the introduction in the company of a production process, a method of service supply or delivery of products, that are new or significantly changed. The result must be significant with regard to production levels, product quality or production and distribution costs " (OECD, 1997).

Whatever its level of implementation (incremental or breach), the concept of technological innovation, is now the most widely used in industry and the one on which the largest number of companies base their work. Indeed, technology has become the main lever for competitive strategy (Ribault et al. 1991). But technological innovation requires technological superiority, and therefore mastery of relevant knowledge.

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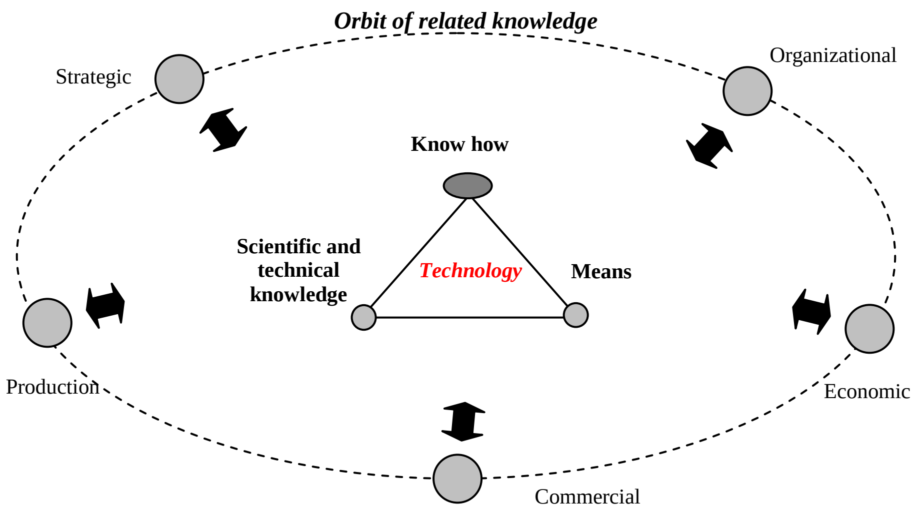
3.2 Knowledge: the Foundation of Technology

In order to define technology as we mean it throughout this document, we refer to the definition proposed by Castagne: "All scientific knowledge, technical and related knowledge, in the face of a market (ie in the face of a client system), in a specific socio-economic environment "(Castagne, 1987). Technology is unique to its environment (business), and constantly interacts with humans and markets. It represents both a social and an economic value. But we believe it cannot be summed up in a set of technical knowledge and related fields. Ribault said that technology is based on the following three components: scientific and technological knowledge (description of physical phenomena), resources (material and human resources), know-how (experience through practice) (Ribault and al. 1991). To these three fundamental components we therefore add 'related' knowledge (economic, strategic, commercial…), which surround either directly or indirectly the technology used for design or production. These various types of knowledge, accumulated and shared within the company, we will be referred as "corporate culture" enriching the three basic components. By definition each technology must merge with its company, it is essential to have these components interact in a state of development, adaptation or settlement. Based on these two definitions, we propose the following pattern where 'related' knowledge is represented by an orbit that revolves around the means, know-how and scientific and technical knowledge involved.

Figure 1 The concept of technology



However, one cannot place these three main components on the same level of acquisition. In our research we believe that know-how may not be obtained without technical knowledge and without means, just as means are ineffective without technical knowledge. We believe that the scientific and technical knowledge are at the heart of technology as it draws on science and technical knowledge to exist. The word technology imposes scientific research and the creation of knowledge. And technological innovation thus necessarily goes through a step of emergence of technical which is not entirely created within the company ('co-development'). Lack of control over this knowledge, for the applicant company, heavily jeopardizes integration of in-house technology in the future.

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It should become clear at this point that the development of technological innovation necessarily generates an impact on the corporate activity. Technology has become, in the space of a few years the major component of competitive strategy, and is now forced to be continuously optimized for increased performance. We have highlighted that many factors must be taken into account in the management of technological innovation. But in order to reach a successful outcome, it is necessary to respect certain conditions, without which this type of project may be doomed to failure.

4 Necessary conditions for technological innovation

Although technological innovation appears to be a strategic gateway to increased competitiveness, it is nevertheless true that many companies are experiencing bitter failures in this area. If we look at results of an investigation by the French Ministry of Industry, 60% of innovative businesses delayed their innovative projects and 37% of them dropped out between 1998 and 2000 (SESSI, 2002). Therefore, there are many barriers to innovation in SMEs as well as in large groups. The main factors of failure are identified (Mabile, 2002): lack of team adherence to the project, gaps between the initial expectations of the market and the end product, lack of quality and reliability in the product, arrival of a more innovative product on the market before term, and also difficulties in mastering technical and industrial processes. The latter factor is, in our view, prevalent in the failure of innovative projects. The lack of in-house technical resources (technology with strong scientific knowledge, for example) leads makers to set up collaborations with research centres and experts (Boly, 2004; Legardeur, 2001; Mercier, 1998). This approach allows the gathering of knowledge and skills in business areas other than those of the company. This diversification leads to changes in scientific and related knowledge aiming to improve the competitiveness of the company

But these collaborations or partnerships further emphasize the difficulties in controlling technical processes. Indeed, if the company is unable to acquire part of the techniques developed abroad, the technology cannot be sustained within the company since no-one, within the company, will have the capacity to make it evolve further. We therefore support that, in order to control and integrate future technology in the enterprise, it is necessary to transfer, manage, create and capitalize on all technical knowledge throughout the design process.

Many writings on the development and integration of innovative technologies concur in proposing six conditions for success (Cadix and Pointet, 2002; Iansiti, 1998; Mercier, 1998; Ribault et al., 1991): Follow a structured approach, Adapt the process to the company (the new technology should be in harmony with the values of the company and its current structure), Involve outside firms, Create and take over future technology, Anticipate unexpected interactions (to be able to determine the problems related to integration of this new technology before its physical integration,), Take into account social and cultural settings.

The fourth condition, 'Create and take over to the future technology', concurs with our previous statements. However, none of these authors offer a formalized approach which could serve as a frame of reference for project managers who wish to learn and master the technology being developed. We postulate that the establishment of a rigorous collaborative approach, will not only optimize design activities, but also support management and capitalization of technical knowledge. Indeed, as Midler said, the presence and meeting of experts from various trades is not sufficient to guarantee and build collaboration (Mabile, 2002; Midler, 1993; Sardas et al., 2002). Close and effective communication can rarely be created innately, so it is necessary to build a space of exchanges with other partners. The effectiveness of our approach can be seen through the development of exchange protocols, formalization of specific documents, control over flows of data, information and knowledge and creation of common knowledge (Roulet, 2006).

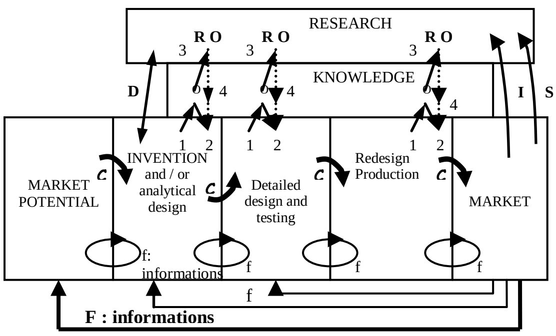
5 Suggestion of a collaboration model

The "co-development" of a new technology must be supported by close and strict collaboration if we are to guarantee its integration (control and durability). So we wish to model a collaborative process that will optimize and formalizing exchanges between external partners and the project manager.

5.1 Collaboration within technological innovation

In focusing on modelling the process of technological innovation as described in the literature, we note that only 'organic' models (those nearest to the industrial reality) depict interactions between design and external areas of expertise. Among these models, Kline and Rosenberg’s is the most representative of the phenomenon of collaboration during the innovation (Kline and Rosenberg, 1986).

Figure 2 Chain model interconnected [Kline et al. 86]



The authors describe an area of research, called "the sphere of knowledge", which brings forth the knowledge and technical expertise lacking in design of the new technology (Perrin, 2001).

Interactions between the design and research processes are still implicit and very little formalized in existing models. When innovative companies must rely on outside entities (research centres or enterprises experts), with little or no experience of how they should work together to "co-develop" a product, these models do not help to control the flow of knowledge transferred and created during the project.

In addition, other authors advocate certain conditions necessary for a successful external collaboration aiming for technological innovation (Bougrain and Haudeville, 2002; Lundvall, 1993):

- Definition and mutual understanding of the needs of each employee to promote the technical learning.
- Construction of a common technical language for communication and exchanges.

Unfortunately, none of these authors suggest an implementation procedure to establish these conditions in the field. Given the limitations of these models and requirements, we wish to provide a model of the process of collaboration, to provide support for the design process, geared towards the leaders of innovative projects. This will facilitate the integration of new technology by optimizing the transfer and capitalization of technical knowledge created internally and externally.

5.2 Overview of the model

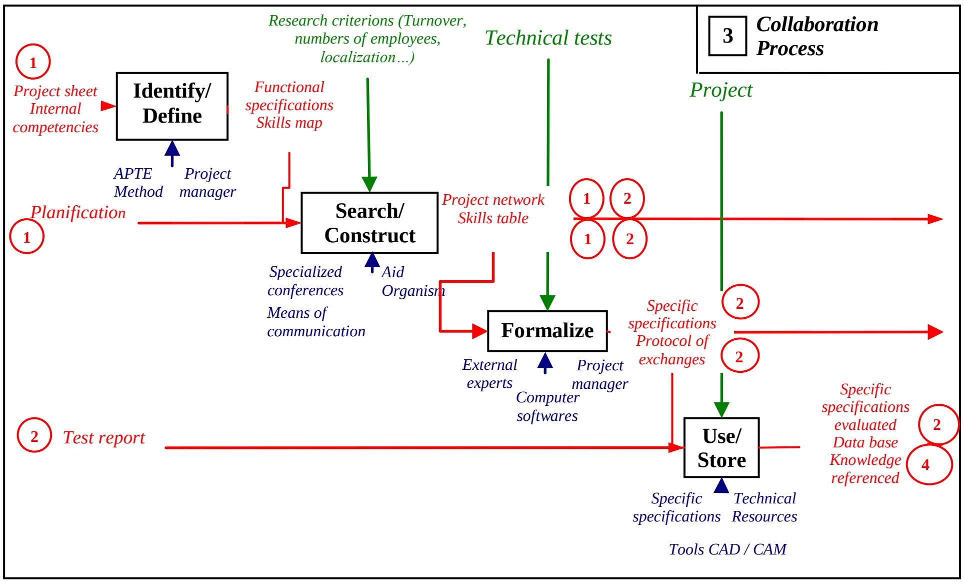
We chose to represent this collaborative process, using SADT (Structured Analysis and Design Technique) modelling. It presents a formalism and a breakdown in tasks, which is understood by the majority of industry employees. In order to give flexibility to those users in achieving technological innovation, we are limited to a representation of A0 level. This collaborative process, whose main objective is to promote communication and exchange with external actors, is organised into four stages: Identify / Define, Search / Construct, Formalize and Use / Store. It is controlled by the project manager and is in constant interaction, throughout the innovation process, with a design process and a process of project management (figure 3).

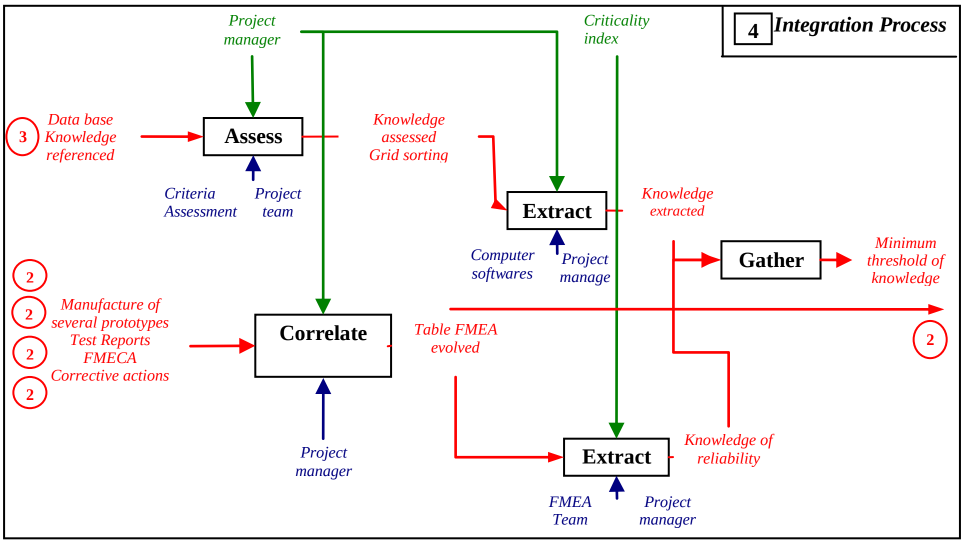
The phase of identification and definition is launched once the 'detailed project' is defined (strategic objectives, project manager, departments involved in the project and technical definition of the concept…). Starting from the definition of the technical concept and assessment of internal skills in the company, the project manager should identify the skills necessary for the external design of the technology. To do this, he constructs a 'skills map' which allows him to record all the technical fields to be used during the project (Roulet, 2006). At the same time, he performs a functional analysis of the system of collaboration in order to translate the fundamental needs of collaboration and identify functions that will allow more intensive and efficient design.

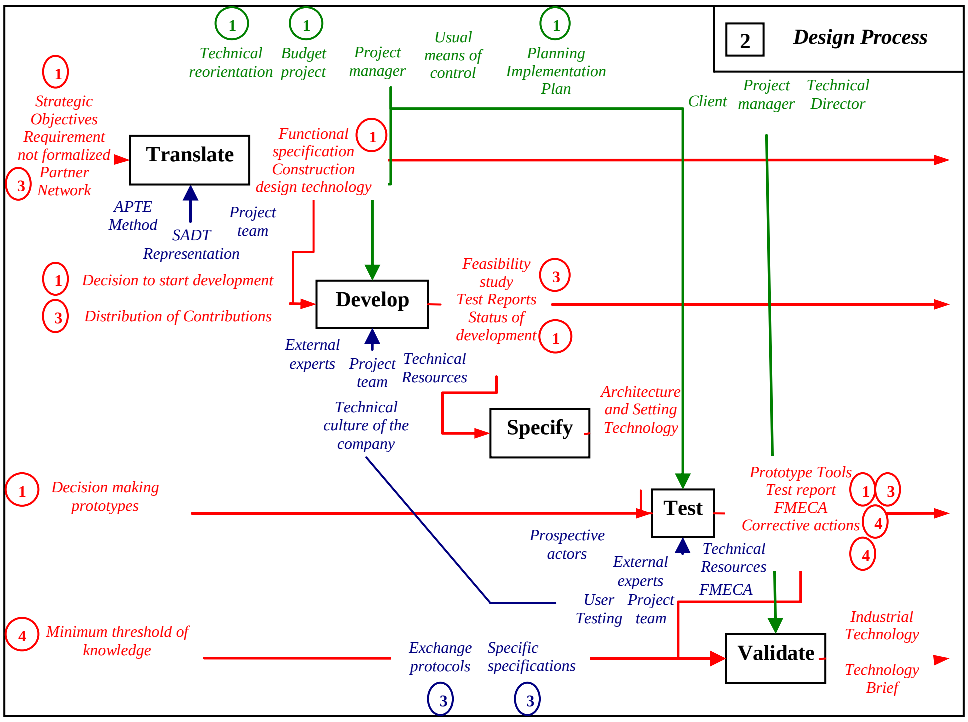
Once these skills are identified, the project manager must contact future actors. He draws upon his business network or participates in specialized seminars to constitute the 'project network'. Thanks to the planning done during the process of project management, he will attributes expected contributions to each member of the network during the technical stages of the project: this is the 'skills table' (Roulet, 2006). This work then gives a fairly accurate prediction of persons or entities most influential to development (the most frequent exchanges and those richest in technical terms). Emphasis must be placed on collaboration with these actors.

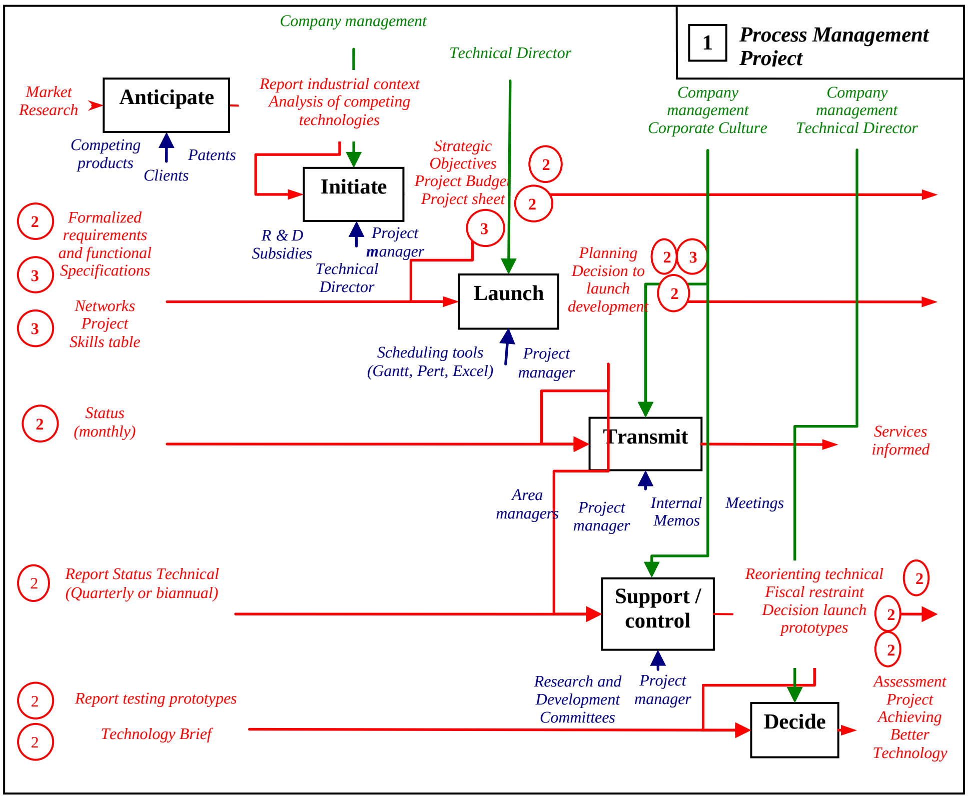
The goal of the formalization stage is to establish rules of interaction between the project manager and external actors. Through meetings, the parties will establish, by mutual agreement, an exchange protocol to define procedures and communication materials. These allow the transmission and reception of data, information and knowledge required for effective collaboration. The establishment of this exchange protocol will lead to the establishment of documents supporting communication (procedures, reports, specifications …). This stage leads to the materialization of the contents of exchanges and their structure. Thus, the project manager prepares the fundamental conditions to control the entire flow of communication throughout the innovative project.

Figure 3 SADT model of the collaboration process and its interactions with others process, the numbers of inputs and outputs correspond to the numbers of different processes




4 Integration Process
Project manager
Criticality index
3 Data base Knowledge referenced
Assess
Knowledge assessed Grid sorting
Criteria Assessment
Project team
Extract
Knowledge extracted
Computer softwares
Project manage
Gather
Minimum threshold of knowledge
2
Manufacture of several prototypes
Test Reports
FMECA
Corrective actions
Correlate
Table FMEA evolved
Project manager
Extract
Knowledge of reliability
FMEA Team
Project manager


2 Design Process
1 Technical reorientation
1 Budget project
Project manager
Usual means of control
1 Planning Implementation Plan
Client
Project manager
Technical Director
1 Strategic Objectives Requirement not formalized
3 Partner Network
Translate
Functional specification 1
Construction design technology
APTE Method
SADT Representation
Project team
1 Decision to start development
3 Distribution of Contributions
Develop
Feasibility study 3
Test Reports
Status of development 1
External experts
Project team
Technical Resources
Technical culture of the company
Specify
Architecture and Setting Technology
1 Decision making prototypes
Test
Prototype Tools
Test report
FMECA
Corrective actions
1 3 4 4
Prospective actors
External experts
Technical Resources
FMECA
User Testing
Project team
4 Minimum threshold of knowledge
Exchange protocols 3
Specific specifications 3
Validate
Industrial Technology
Technology Brief



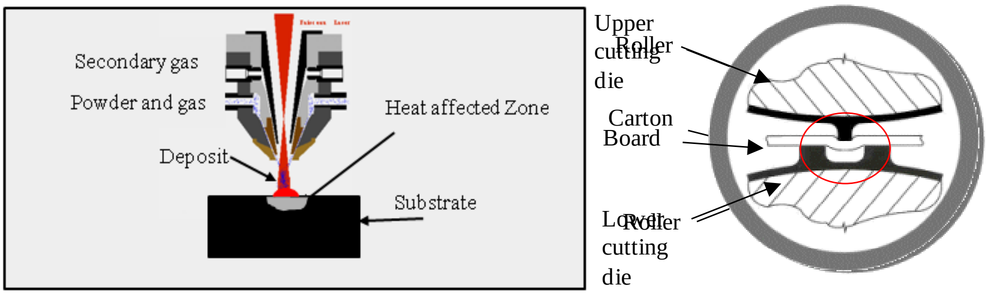
The use of all these documents during the stages of technology design, will initiate the stage of use and storage of this collaborative process. Indeed, experiments on the documents will allow not only optimization, but also storage of their content. The project manager will then record and archive all technical knowledge created along the development. Technical knowledge, the foundations of the control of technology, will then promote its integration. The knowledge base constructed in this way, will expand throughout the innovation process.

5.3 Deployment and Results

We have experimented this model of collaboration in a project aiming to design a new technology of laser cladding dedicated to the manufacture of cutting tools. The technology developed in this project had to call upon several specific and nontrivial technical aspects which were new compared to applications currently in use in several areas of industrial development: precision in the deposit (to 1/100th of a millimeter), use of specific materials, no tolerance to weaknesses in this deposit (porosity, cracks, gaps in the matter) and the ability to engrave the deposit (machining at 1/100th of a millimeter).

This new process has the ultimate objective of reducing costs and delays (by 30 and 40% respectively) related to tools produced by the company for which we work.

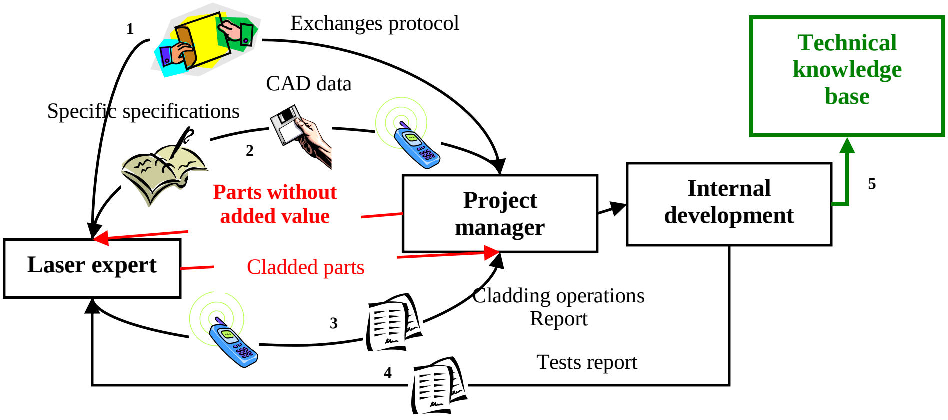
Figure 4 Example of laser cladding and application to cutting tools (Roulet, 2006)



As a first step, we identified all technical areas and related components to be involved in the project: the field of metallurgy, laser technology, the field of machining and the field of rotary cutting. The construction of the ‘skills map' allowed us to validate the external expertise which had to be called upon (experts in metallurgy and laser technology). We then established and prioritized the functions of our system of collaboration, by assigning to each of them some assessment criteria: exchange protocols, means of communication, common knowledge and costs and delays of design.

The breakdown of each of the following stages of the project, highlighted the major involvement of the laser expert in the design of technology. This prompted us to focus the formalization of our collaboration with the main partner in building an exchange protocol. Several workshops allowed us to define everyone's expectations in order to optimize the coordination of development activities. The laser expert lacked information about cutting tools (references, technical characteristics…), but also asked for some feedback on the nature and results of the internal post processing made after the cladding tests. On the other hand the project manager was requiring a written account of cladding procedures carried out by the expert, and a history of changes made to settings during development tests. These sessions allowed us to reach an exchange protocol divided into five parts: the principle of the protocol, the objective of the protocol, its rules of implementation, the pattern of exchanges and the common means for communication (Roulet, 2006). But the heart of the protocol lies in describing of the exchange modes. We formalized everyone's expectations by writing practical guideline usable by both organizations. It was decided that the expert should write a cladding procedure specifically applicable to the deposit of rotary cutting tools. In addition, the expert will establish a record for each test performed. The company, through the project leader, agrees to provide a set of specifications for each reloading operation. He will also be responsible for drafting a report analyzing post-processing operations (mainly grinding and machining) implemented after each test and transferring it to the laser expert. We propose in the figure below, a schematic representation of communication during a trial as well as the order in which each of the documents are involved.

Figure 5 Overview of exchanges



The exchange protocol thus created is the focal point of collaboration since it materializes the content of the interactions and their scheduling. Thanks to a closer and more rigorous collaboration using the documents constructed in this fashion, we were able to store and archive much scientific and technical knowledge. Such knowledge was proved to have been constructed and created mostly during the development phase of the new process of laser cladding cutting tools. They were classified into three categories: internal knowledge (related to post-cladding operations), external knowledge (related to cladding operations) and combined knowledge (or shared knowledge). Each of them was referenced according to documents from which it had been extracted (specific specifications, test reports, cladding reports, etc.).

Table 1 An extract from the technical knowledge base

Knowledge Type	Réf.	Formalized knowledge	Clad	Subs.	Laser
External	3.8	A cladding through CO_2 laser implies sandblasting parts before operation in order to restrict its reflexion coefficient.	CPM	42CD4	CO_2
Combined	4.1	The sensitive increase of the dilution factor (+ 0.1 mm) has got no effect on deposit hardness	CPM	42CD4	Diode et CO_2
Internal	5.4	An angular tool profile improves its engraving quality as well as its life expectancy	CPM	42CD4	CO_2
⋮	⋮	⋮	⋮	⋮	⋮

In order to identify the specific formalization contexts of this knowledge and facilitate retrieval of technical details, we created a table of references (related to the archiving of documents produced and referred to during the project). Roughly one hundred technical knowledge were been identified in the knowledge base during the 'co-development' of our new manufacturing technology.

Formalization of the technical knowledge transferred and created during co-development therefore requires the development of a close and rigorous collaboration. This will optimize the communication and exchanges with partners.

6 Conclusion

In conclusion, we have shown in this article that to incorporate a new technology after co-development, it is essential to master the related knowledge. But the main factor in the failure of innovative projects is very difficult to implement in the context of outsourcing. The collaborative process presented here proposed encourage closer relations between both sides, during the 'co-development' of the new technology. The exchange of data, views and experiences, but also a common search for solutions, are increasing thanks to the construction and use of shared documents. The trust and precision introduced in this way, strongly contribute to the transfer and creation of technical knowledge. All this enables the company to better manage and control all elements of technological innovation, but also its ability to integrate it and perfect it.

This collaborative process alone cannot guarantee the integration of the new technology. But it is certain that without such rigorous exchange it will be impossible since all technical knowledge created and transferred during the project, will be repatriated within the company.

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