Value indicators and monitoring in innovative PDM: A grounded approach

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ABSTRACT

Long-term success of firms depends on the efficiency of their management of R&D projects. However, there is a gap between standard economic and strategic indicators and the high uncertainty, complexity of commitments, and organizational issues that can be observed in the more innovative R&D projects. This paper presents the results of an eighteen-month study in the R&D departments of Renault SAS, which aimed to develop a new monitoring approach of R&D projects. In partnership with R&D teams and managers, a first empirical research on a sample of 64 projects assessed a series of hypothesis about what could be an appropriate monitoring for highly innovative projects. Then, a new monitoring system was built, based on a triangular approach of the project status: economic performance (value and reliability of the value), strategic potential indicators, organizational impact and resource assessment. This paper describes this model and associated tools, as well as the research methodology used to implement them. This monitoring system is now used routinely in the company.

SECTION 1. INTRODUCTION: IN SEARCH OF MONITORING INDICATORS FOR R&D PROJECTS

R&D project selection and related resource allocation are crucial issues in large industrial firms, and have to be decided at the earliest stages of projects. The selection process goals are double. On one hand, projects must be chosen to reinforce and enable the strategic vision of the firm in order to ensure its durability. On the other hand, monitoring methods should improve the sharing of resources between projects taking into account people's skills and expertise.

However, R&D project selection is a particularly complex problem. There are many interrelations between projects issues and allocated resources as well as an important level of technological risk and market uncertainty – though the latter decreases as the project matures - which cannot be easily measured with quantitative criteria. Furthermore, realistic decision processes depend on the firm habits in portfolio management. It has been observed that R&D actors in large firms do not identify easily internal decision makers and that selection criteria are not really known or accepted by R&D teams. R&D projects tend to be surrounded with internal controversies and need strong political efforts and debates within organizations. Souder claimed that the first function of the selection process is to build commitment and consensus in the firm (Souder, 75).

Yet, such consensus is not an easy target: actually, resource constraints combined with the lack of reliable economic data raise problems to characterize projects values, particularly when they are in the creativity and exploratory phases. Traditional methods of evaluation such as Discounted Cash Flows or risk analysis stumble over this specificity of innovative products. How do firms face such limitations? What type of value indicators and monitoring already exist and which one could be used for innovative PDM? The literature presents a wide range of propositions, however most of them have been criticized for their weak adaptation to R&D projects and empirical studies confirm that few of them are really used in practice.

STATE OF THE ART: THE GAP BETWEEN RESEARCH AND PRACTICE

State of the art

R&D project selection has been a distinctive and proliferating research field since the sixties. Hundreds of papers propose selection models and associated methodologies. Baker & Freeland (75), Hall & Nauda (90), Martino (95), Heidenberger & Stummer (99), Henriksen & Traynor (99) present detailed literature reviews and taxonomies. Most approaches could be integrated in one of the three dominant categories described below.

- Mathematical programming approaches:

Constrained optimization problems are the oldest models developed in literature. They were created to optimize some objective functions, most of the time of economic type, within a set of specified resource constraints. Those models rely on integer or linear approaches (Souder, 73). To be more realistic with project portfolio environment, later models have used non-linear approaches including goal-programming and dynamic formulations. As an answer to criticisms regarding the uniqueness of optimized parameters, earlier models of this category have combined multi-criteria inputs (Ringuest & al, 90) or Monte Carlo simulation methods (Fox & al, 85).

- Benefit measurement methods:
    - Multi-attributes models:

Scoring, ranking and checklist approaches are the oldest multi-attributes methods, mostly designed in order to support peer reviews. These approaches tackle selection issues from the point of view of multiple criteria (Moore & Baker, 67). With the Multi-Attribute Utility Theory, academic models evolved in the late sixties to the building of objective functions that aggregate multiple attributes for use under certain or uncertain conditions (Coldrick & al (2002)). Multi-attribute models with strategic goals often provide an interactive process to capture project information and then assign scores to support decision-making. The most well known approaches in this category are Saaty's Analytic Hierarchy Process (AHP) (Saaty, 80), (Liberatore & al, 95), the Q-sort approach (Mandakovic & Souder, 86) and the Delphi method developed by the RAND Corporation (Athakorn 2002).

- Economic models:

Economic models simulate financial scenarios of expected returns in investments studies. Most common tools are those of physical investment selection: Net Present Value, Internal Rate of Return and Payback methods (Cooper & al, 98). This field is the most important in literature, especially with the Discounted Cash Flow approach (Talias, 2006) and Option Pricing methods, which have been covered by numerous publications in the last decade (Dixit & Pindyck, 94), (Faulkner, 96), (Pries & al, 2001). Economic models come up against data uncertainties: the more models take into account this difficulty, the more complex they are to use and finally appear like black boxes to industrial decision makers.

- Ad-hoc models:

Numerous ad-hoc models were born from the collaboration of academics with industrial managers. These methods contain statistical approaches, cognitive emulation models (Schwartz &Vertinsky, 77) and Decision Theory (Mandakovic & al, 85).

A gap between the literature and observed practice.

Since the 70s, Souder (75) and Baker & Freeland (75) criticize the ill-treatment of data uncertainty and multiple criteria in the classic approach (constrained optimization approaches). Souder explains that the first key of selection tools is to build an internal consensus and commitment around R&D project. Schmidt & Freeland (92) insist on the need to take into account the organization in the decision process model: "Process [of project selection] requires the coordination of a variety of organizational subunits at varying levels within an organizational hierarchy".

Lawson & al (06) explains that small and medium-sized firms' managers do not use selection tools and rely more the experience of a senior manager, and avoid investing in tools and methods that require costly training and maintenance. This argument is also partially right for large firms where senior management judgment is often the traditional way of selection for R&D projects. Nevertheless, senior managers' ability to control an R&D strategy could be discussed by project leaders and most large firms try to develop grounded and credible monitoring processes that could be accepted by all R&D stakeholders. Within such perspective, Cooper, Edgett & Kleinschmidt (98) underline that hybrid models, which combine two or more of the previously described tools, are dominant in new product development best performers. Moreover, ergonomic presentations and user-friendly tools seem as important as indicators accuracy. Their surveys show that Economic tools are the most used, followed by scoring tools.

Finally, one can agree with the requirements established by Cooper & al (Cooper & al, 2004a) that "senior management must lead the way in NPD, providing the leadership and committing the resources" and that there is the need for the formulation of a product innovation and technology strategy and the monitoring of R&D project portfolio adequacy (Cooper & al, 2004b). Yet, table 1 summarizes the present gap between existing tools and their observed implementation in companies.

	Models from normative literature	Empirical observations in companies
Economic Performance	Discounted Cash Flow or Option Pricing tools	Little use owing to the ill-treatment of data uncertainties and weak reliability. (Hastabacka,2004)
Adequacy to Strategy	Portfolio management tools	Use in project selection process. Existing tools are not suitable to monitor the strategic adequacy of projects in progress (while firm's strategy could itself evolve).
Organization ability	No existing tool except for resources allocation	In practice, firms rely on senior management to structure , lead and involve R&D contributors and stakeholders

Table 1: Academic tools of R&D project valuation and their industrial uses

Obviously, there is clear goal for research in reducing this gap and finding new ways to build monitoring systems for R&D projects. This has been the main purpose of our research program which central hypotheses are derived from the preceding state of the art.

THREE HYPOTHESES ABOUT RELEVANT MONITORING TOOLS FOR INNOVATIVE PDM

From a research point of view, and according to existing state of the art, we have made three preliminary hypotheses about what could be the main features of relevant systems:

1. **The more a project is innovative, the more economic information has to go with reliability indicators to be useful to decision makers.** Most firms routinely use profitability measurement tools (most of the time Net Present Value) to manage their investments and their product development projects. Yet, using the same tools for R&D projects would face well grounded resistance. All R&D leasers and stakeholders are aware of the high uncertainties about customer value, technology validity or production costs that are specific of innovative products. However, resorting to such economic value indicators becomes reasonable and necessary as soon as the technical and market choices of a project reach some maturity and stability. Therefore, the real issue becomes: when R&D managers can really trust economic evaluations of their projects? Consequently, we assume that the development of reliability indicators of the economic information is a key issue for the acceptance of economic performance evaluation in R&D projects. Moreover, we expect that the more innovative is the project, the more R&D managers will condition their acceptance of economic evaluation to a clear assessment of their reliability.

2. **The more a project is innovative, the more a multidimensional strategic value assessment is needed to build commitment and consensus about the adequacy of the project to the firm's vision.** Economic criteria are insufficient to characterize innovative project value because they neglect the non-monetary impacts of R&D projects such as: creation of new competences, brand reinforcement, and access to new markets or new innovative design spaces (Hatchuel & al, 05). Thus, we assume that the more innovative is an R&D project and the more these impacts are varied and should be strategically assessed. In the literature, models using qualitative criteria lead mostly to an aggregation of criteria in order to locate a project in relation to other R&D portfolio components or with regard to a threshold level decided beforehand: it is the usual way of benefit measurement models. These aggregations blur the disparity and origins of strengths and/or weaknesses of an innovative project. In contrast, we assume that distinct strategic goals and potentials play an important role in the monitoring of R&D projects, leading to decisions that could be in contradiction with economic evaluations of projects. Moreover, commitment and consensus could be better achieved when project teams and stakeholders share multiple views of the strategic impact of a project.

3. **The more a project is innovative, the more an appropriate organizational structure must continuously back up the project in order to support the creation of new competences creation and stimulate the commitment of key players inside or outside the company. Thus, we assume that an evaluation of such organizational**

backup will be a key monitoring element in R&D projects. It is well-documented observation that innovative products induce variable support or even rejection from functional and operational departments of the company. These reactions, if they are not taken into account, could either increase the project development delays or endanger its survival. Therefore, we assume that the more a project is innovative, the more project leaders would welcome a continuous identification of their organizational supports or threats. However, such indicators of organizational commitment are not much developed in the literature.

SECTION 2. RESEARCH MATERIAL AND INVESTIGATION METHODS

To test our hypotheses, we have set up a research project in partnership with the global car manufacturer Renault SAS. We received full access to a sample of 64 R&D projects representing a large variety of technological domains (electronics, acoustics, aerodynamic, combustion, etc.) and a wide range of research team sizes (up to dozens of dedicated experts). Three months after the beginning of this study, R&D actors proposed new projects to renew one third of the panel and a year later, the project portfolio was again changed by approximately a third. R&D projects selection and monitoring issues are particularly sensitive in the car industry because of strong constraints on available resources and due to the high impact they can have on the success of a new vehicle.

Projects sample and comparative material with other studies.

The distinctive features of the studied project portfolio lie in its technological and organizational variety: projects have very different technical challenges or stakeholders' combinations. Our approach differs also from the majority of studies on projects valuation and selection by our statistical approach of resource commitment on projects. Usually, research leans on managers and decision makers' interviews to understand their choice criteria and rationale. In this study, we also interviewed periodically project leaders and decision makers. Yet, in addition, we had access to detailed analysis of projects, budget allocations and supports, as well as project teams' composition and evolution (internal actors and suppliers). This longitudinal study has been performed over eighteen months.

Innovative level of projects.

All project leaders and managers were asked to evaluate the innovative degree to their projects according to a simple three levels scale, which is commonly used in the automotive industry:

Type 1. Improvement and performance on a standard component or function

Type 2. Development of a new function of the car or a new manufacturing process

Type 3. Major change in system, architecture or energy

Table 2 describes the distribution of the projects on this scale. It also highlights the diversity of projects in our sample from two points of views: Project size and cross-disciplinarity.

Identification of strategic value dimensions and outputs of projects.

At the same time, a workgroup of about ten Renault R&D specialists was set up to characterize the non-economic dimensions of an innovative activity and to suggest progress ways. The workgroup was composed of researchers and members from marketing, strategy and economic studies. We have run this group in monthly meetings for over one year. Members of this workgroup have been selected for their large experience as R&D project leaders, R&D experts or as internal customers of R&D innovations (industrial development teams).

	Project innovative degree		
	Improvement and performance on a standard component / function	Development of a new function of the car or a new manufacturing process	Major change in system, architecture or energy
Number of projects	38	18	8
Project size			
Renault teams (members)	Single to a few dozens people		
	Smaller and medium	Largest	
% of R&D Budget	50%	30%	20%
Length	6 months to 2 years	1 to 3 years	> 3 years
Cross disciplinarity of the projects			
Nb of Renault departments involved	1 to 7	1 to 6	2 to 9
Nb of projects with external partners	14	6	4
Project Monitoring			
Resource allocation and consumption	All projects (monthly report send to R&D managers and teams leaders)		
Selection and orientations meetings screening	78	42	23
Nb of project screened in details seeking decision repercussions across regular deep interviews	12	14	8

Table 2: Projects sample innovative degrees and monitoring methodology

Finally, all this material was systematically structured in order to discuss our three previously mentioned hypotheses. Our intention was to use this series of analytical results, as a template for the design of a new monitoring system that will be described later on.

SECTION 3: WHAT IS EXPECTED FROM A MONITORING SYSTEM FOR R&D PROJECTS? AN EMPIRICAL ASSESSMENT OF OUR HYPOTHESES.

The first analytical results showed a good confirmation, qualitatively and quantitatively, of our three hypotheses.

H1: Use of economic indicators (NPV).

Table 3 summarizes our observations about the reliability and use of economic indicators according to project maturity. We have been able to distinguish between three phases of maturity for each project (creativity, exploratory and validation). For Type 1 projects, NPV calculation did not raise particular problems, especially in validation stage where the most of them have significantly reduce data uncertainties. Yet, for Type 2 projects, NPV was systematically viewed as a controversial indicator in all orientation committees. Most projects nevertheless computed their NPV to comply with management recommendations but they declared, when interviewed, that NPV could not be used without a clear explanation of scenario hypotheses and data uncertainties. For Type 3 projects, NPV value was denied. This type of projects is composed of breakthrough innovations which outputs are very uncertain and risky. Therefore, orientation meetings rejected the discussion of NPV criterion.

Project Maturity Stage			Creativity		Exploratory		Validation	
Data reliability			Unknown	Under control	Unknown	Under control	Unknown	Under control
% of sample projects	Type 1	Customer Value	85	15	50	50	10	90
		Expected sales	50	50	25	75	0	100
		Production costs	35	65	10	90	0	100
	NPV Calculation			Not use		30		**90**
	Type 2	Customer Value	90	10	75	25	50	50
		Expected sales	60	40	40	60	25	75
		Production costs	50	50	25	75	10	90
	NPV Calculation			Unrealistic		15		**60**
	Type 3	Customer Value	100	0	90	10	90	10
		Expected sales	100	0	90	10	70	30
		Production costs	100	0	50	50	35	65
	NPV Calculation			Unrealistic		Not use		**25**

Table 3: Reliability on key economic data according to project maturity

Thus, empirical observations tend to validate our hypothesis that the use of economic indicators is strongly linked to their perceived reliability. Therefore, economic reporting of R&D project should routinely present a reliability index of these indicators. In highly innovative projects, it is unlikely that these indicators will be accepted before a significant maturity of the project is reached and economic uncertainties are convincingly reduced.

H2. Strategic dimensions of an R&D project: an implicit agenda.

The strategic potential of an innovation product was usually mentioned as a key yet informal judgment that lacked stable consensus and explicit analytical grids. Through interviews, R&D project leaders and managers criticized the lack of explicit company road map on strategic objectives. They claimed that, in most cases, projects fell within the scope of local road maps, built by functional experts. Therefore, these road maps could contradict each other's and would receive no support from a company selection board. Table 4 describes the main consequences of a lack of strategic monitoring as they were described by R&D players according to the degree of innovativeness of the project. Obviously, Type 2 and Type 3 projects were suffering more than Type 1.

Not surprisingly, these R&D projects declared that they were interested in tools helping to structure and compare long-term strategic value of R&D projects. Type 2 and Type 3 projects need clear strategic positioning because they are the most risky projects. Adding an innovative function to the car or modifying vehicles fundamentals, these projects need to be very strongly supported by a global strategy of the firm otherwise they will never obtain the required commitment from all stakeholders. No car project manager wishes to accept in his project an innovation, which could endanger the whole development of the car, unless there is a clear strategic option continuously defended by top managers since the beginning of the project.

The 10 outcomes of formalization lack on strategic objectives
By order of most often underlined during deep interviews of R&D stakeholders

		Type 1	Type 2	Type 3
1.	Projects "Politicization" between stakeholders			X
2.	None commitment of internal customers or vehicle target teams			X
3.	Functional Road map have no legitimacy in others departments		X	X
4.	No coherence between projects in theme portfolio		X	X
5.	Ambiguous objectives		X	X
6.	Innovation fields badly exploited		X	X
7.	Evolution of objectives at each orientation meetings		X	X
8.	Projects interdependence hardly comprehensive	X	X	X
9.	Concurrent or antagonists projects co-exist	X	X	X
10.	Partially similarly projects co-exist without connections	X	X	X

Table 4: Stakeholders fears about strategy formalization blanks

H3. Evaluating the organizational support and impact of projects.

During major "Go / No Go" meetings, the organizational support or impact of an R&D project was often mentioned, yet without any systematic data support. Project leaders often insisted on the idea that systematic control of resources availability and organizational capacity should focus on project needs for completion. Type 3 projects were the more concerned by this issue as they appear to need a high level of organizational flexibility to reach completion. In most meetings, they were facing unexpected issues that could not be solved without some extra commitments from other departments or without external competencies.

Finally, the first step of our longitudinal research empirically grounded our research hypotheses. The monitoring of R&D projects should comply with specific requirements about the reliability of economic indicators and should systematically provide strategic and organizational evaluations of the projects. In addition, the more innovative is the project, the more such monitoring should be rigorously designed following these requirements. This is why our research program took an experimental turn with the attempted implementation of a new threefold monitoring.

SECTION 4: EXPERIMENTING A NEW MONITORING FOR R&D PROJECTS

Based on the analytical results of our study, we are currently experimenting a new monitoring system that is developed especially for Type 3 projects, which are the more challenging to assess and monitor. Our model is based on a triangular approach of the project value: i) economic performance (seen as value and as reliability index of the value), ii) strategic value indicators, iii) organizational impact and resource assessment.

i) To meet the needs of structuring the economic communication, we built a set of economic indicators that depend of the level of project maturity. These indicators are associated to a reliability index; in addition, some rules define how uncertainties about economic data should be presented. The first type of economic data collected by R&D project teams are about benchmarking and existing markets. After a technical concept is chosen, costs begin to be estimated. Data becomes more reliable when project maturity increases and during the last months of the project as illustrated in Figure 1 below:

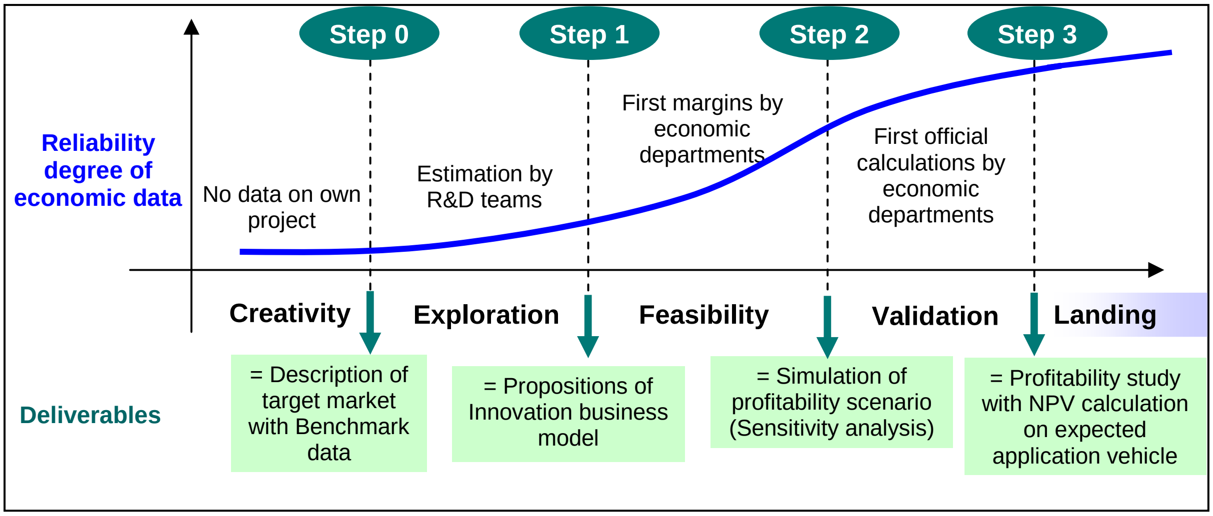

Figure 1: Reliability on economic information

ii) The second part of our monitoring model is a dynamic characterization of the strategic value of the innovative project for the company. We suggested a diagnosis of the created value by a R&D project. The goal is to describe the various forms of value creation associated to a R&D activity considering all occurred effects and not only the expected final product. This approach implies the consideration of the following points:

- the project fit with the company's strategy and future regulations;
- the creation of knowledge through the opening of various new innovation fields;
- the volatility of internal expertise that contains the firm's future potential innovative capital;
- the impact of studies on firm internal performance.

The main of our work was to build the index of potential effects that are value creators in R&D activities. This axis began with the sharing of definitions for keywords on each field and the search for concrete examples of value creation with R&D members. Then, having built the thematic directory of value creation forms in department activities, we identified existing indicators to assess these effects in the company. We proposed others in case we judged they were incomplete or in contradiction. This stage has allowed us to define the scope of quantitative indicators to deal with the value of an activity. In contrast, we began the construction of a qualification vocabulary of the value creation specially dedicated to our application field. Finally, with the contribution of a group of R&D managers, we have built a diagnosis tool of value creation, which helps an R&D project leader to detect potential sources of value creation of his research activity.

Value Creation	Firm Strategy Adequacy
	Services and regulations earnings
	Internal performance earnings
	Cross disciplinary efficiency
Management quality	Intellectual property and Risk management
	Brand image enforcement and communication
	Resources and cooperation management
	External partnerships

Table 5: Value Levers of a project

Table 5 shows the main items of this diagnosis tool. Each item can be evaluated through a multiple-choice questionnaire. At present, the tool contains forty-five questions grouped together in two parts of four themes in respect of the value levers cartography. We called it Review of Valuation Criteria (RVC). Several testing sessions on projects in progress have strengthened the formulation of the questions and proposed answers so that their meaning is collectively accepted. The language used in the tool is the technical and organizational language of the company.

The questionnaire comes along with a reading grid that synthesizes on a sheet the strengths, assets and risks for the activity, according to a standard formulation. This index card is the diagnosis of the value creation and the risks of value destruction of the activity: as the questionnaire is a dedicated tool to project instructors, as this index card can be shared to help the decision during the stages of selection and orientation of a project. The suggested tool is the convergence of all works realized in the workgroup. However, one of this tool’s objectives is to provide help to the decision board in the selection and the ranking of the research subjects. To this end, we have sought the view of all key actors taking part in the R&D management so that they criticize, put forward propositions of reinforcement and validate the RVC tool. Therefore, the last phase before deployment contained numerous tests and numerous sessions of validation consultation. The tool in its current shape is now in deployment in R&D entities that have already validated the RVC and workgroup members receive in return numerous and very positive feedback from both operational and managers. We currently lead this deployment of the tool in the whole company.

iii) The third axis of our model is about the characterization of the organizational needs of an R&D project at each stage. Currently, there are two standard structures: coordination by a project leader of experts dispatched in technical fields departments and, composition of a project team by the temporary concentration of technical actors in a dedicated workplace. Practical analysis shows that hybrid structures could be most efficient to commit functional actors as well as decision makers according to some projects coordination needs. Therefore, a set of conceivable structures has to be characterized and the matching between project needs and optimal organization has to be monitoring. The most a project is innovative, the most the structure choice is decisive for an optimal development of the innovation.

This axis partly corresponds to the budget needs of projects. At first, we developed a monthly monitoring tool of comparison of budgeted versus realized resources

consumption. Diffused to R&D project leaders and their management, this tool operates like a warning signal in case a sector has exceeding resource consumption or a poor financial commitment. This information is given in short loop towards a technical progress: it is one way to alert if projects need resources or competence adjustments. However, this approach is insufficient because it does not allow more than corrections of a preexisting project organization and does not give an organizational proposition at the project launch or at important steps. The RCV tool previously described covers a part of this characterization. Items on the management and organizational quality describe the optimal constitution of the internal teams in numbers and in competence for the company's current structure as well as the actors, academic and/or the suppliers, necessary for the project completion. This data allow R&D entities, in association with the management control, to develop the composition of teams towards the structure and the mode of financing identified as optimal.
However, we currently work on a characterization of project features indicating from the first stages of development that the studied subject requires a more marginal structure for the automotive sector such as Joint Venture, externalized R&D entities or incubator. This need arises in projects that issues go away from the heart of historic profession of the car manufacturer.

Joining our three axis of value, we obtain the following model for the monitoring of R&D projects according to the maturity of the activity (figure 2):

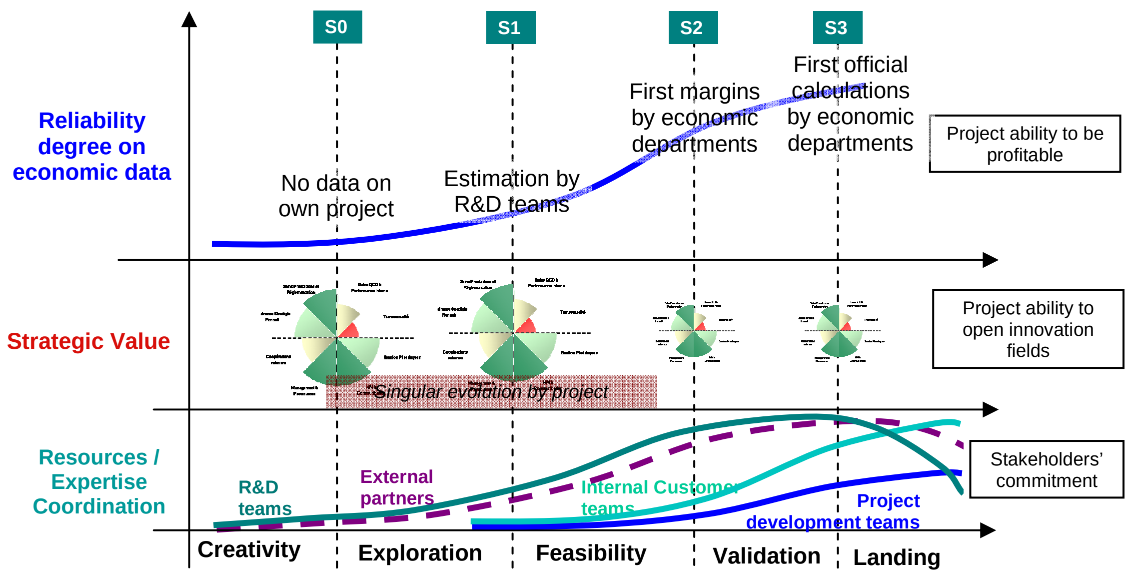

Figure 2: Three axis of the monitoring model

DISCUSSION AND CONCLUSION

The present state of our experiments allows asserting the validity of our hypotheses and the efficiency of the original monitoring structure presented in this paper. We have built tools in partnership with research teams and R&D managers. Such monitoring work is now routinely implemented and well accepted. It has allowed building an important database on internal R&D financing, as well as a good knowledge of economic and strategic valuation in project life. In practical terms, our data base fully indicates the resources involvement as well as their realization structure (hierarchical joining and geographic localization of internal actors, type of suppliers' contracts). Secondly, budgetary and/or realized economic allocations signal the commitment of a department to some project. This allows reconstructing project support or rejection by key actors of the company (technical experts, prototype teams, internal customers, drafts vehicles teams).

In contemporary companies, R&D managers need help to allocate resources, generate strategic consensus and orient their projects. This research offers a new monitoring system which has been grounded on a unique sample of diversified R&D projects. However, our hypotheses as well as the principles of our monitoring can be easily transferred to other companies and contexts. Further research should extend the empirical grounds of our approach.

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