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Measuring the supplier's performance in collaborative design: Proposition of a model

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Abstract

An important trend in New Product Development Projects (NPDP) is to extend the involvement of suppliers in order to enlarge the scope of the firms' competencies. Thus, the focal firms in this activity of network design express a need for methods and tools in order to effectively manage these particular relations which we call in a generic way *collaborative design*. This paper is the first step of an on going research aiming at describing the issue of supplier performance evaluation in this specific context. The model presented in this paper was built with the collaboration of six French industrial manufacturers, partners of the PRAXIS research project (Performance in Relationships Adapted to eXtended Innovation with Supplier).

Keywords: NPDP, collaborative design, supplier performance evaluation.

Educator & practitioner summary

For practitioners we present an operational model for the measurement of supplier's performance in collaborative design. This model is also inspired by 6 case studies representing various industrial contexts. For educators this article provides empirical materials on the up-to-date subject of supplier involvement in NPDP.

1. Introduction

Today, in numerous industrial sectors, the competitive context can be characterised by two antagonistic phenomena. On the one hand, the complexity of the products is increasing, due to an integration of various technologies during the product's development phases. On the other hand, the companies are concentrating on their core competencies which induces an acceleration of the *impartition* policies (Barreyre, 1988) where the firms decide to choose the contracting-out solution rather than the in-house one. We can observe that this decision is not limited to production activities. When the firms contract out, they often decide to transfer the responsibility for the design and the engineering activities of the outsourced component to suppliers too. These two phenomena emphasize the importance of what Van Weele (2003) calls Supply Resources Management and particularly for the purchasing agents, they must mobilise external capabilities in the New Product Development Projects (NPDP). As Dyer and Singh (1998), we thought that the message induced by the Resource-Based View¹ (RBV) of the firm (Barney, 1992; Wernerfelt, 1984) must evolve into a new *relational view* of the performance of the firm. Indeed, in many sectors, as the potential of innovation is beyond the

strict boundaries of the customer's company, one of the principal ways to reach a competitive advantage is to generate a *relational rent* (Dyer and Singh, 1998) due to the joint idiosyncratic contribution of the partners. That's why the suppliers are obliged to develop pro-active strategies in order to become a *preferred* partner for their customers in their NPDP. The customers have to develop a specific know-how in terms of supplier involvement in such projects. So interaction in NPDP is surely the most interesting arena to study the *relational rent* constitution *in vivo*.

For the Purchasing point of view, supplier selection and supplier performance evaluation processes are two crucial managerial issues to create this *relational rent* in NPDP. Indeed, the customer firms have (a) to evaluate not only the supplier's capability to answer their requirements in terms of costs, quality and delivery but also in terms of ability to collaborate on the design activity and to provide the needed technological competencies. Furthermore, once the supplier is involved in a specific project, they wonder (b) how to measure the real contribution of the supplier with tangible and objective performance criteria.

The study of both these processes is one of the main goals of the PRAXIS research project developed within the French Cluster "Arve Industries Haute Savoie Mont Blanc"ⁱⁱⁱ.

In this article, we focus on the evaluation of the supplier's performance in collaborative design. Our objective is to provide a generic model of supplier performance evaluation that takes into account the various situations of collaborative design with suppliers.

Section 2 is devoted to the definition of the scope of collaborative design and a presentation of the state of the art on supplier evaluation in NPDP. The research methodology is presented in section 3. Section 4 focuses on the presentation of the model of suppliers' performance evaluation in collaborative design.

2. State of art on supplier evaluation in collaborative design.

2.1. Collaborative Design in NPD: What does it mean?

The supplier performance evaluation model presented in this paper is dedicated to the different collaborative design situations that occur between a customer and its suppliers in NPDP. Thus, in this section, we present what we mean by collaborative design in NPDP. For that, we use the *Supplier Involvement Portfolio* developed by Calvi and Le Dain (2003) that allows the identification of the different situations of supplier involvement in NPDP (Figure 1a). The authors have enriched the model developed by Wynstra and Ten Pierick (2000) and characterized five situations of supplier involvement based on a two-dimensional matrix. These dimensions are: (1) the degree of autonomy granted to the supplier in the product development process, and (2) the collaborative development risk linked to the outsourced component. In their matrix the degree of autonomy is a 5 scale model function of (a) the supplier's know-how deployed in the NPD process (Wynstra and Ten Pierick, 2000; Clark and Fujimoto, 1991), (b) the role played by the supplier and the customer in product development (Kamath and Liker, 1994) and (c) the proprietary nature of the produced knowledge technology and drawings (Bidault et al., 1998; Fujimoto, 1995)ⁱⁱⁱ. The second dimension is determined from six combinatory types of product development risks. This evaluation allows the identification of the dominant risks within the product development project and by doing so the definition of any measures required to control these risks^{iv}.

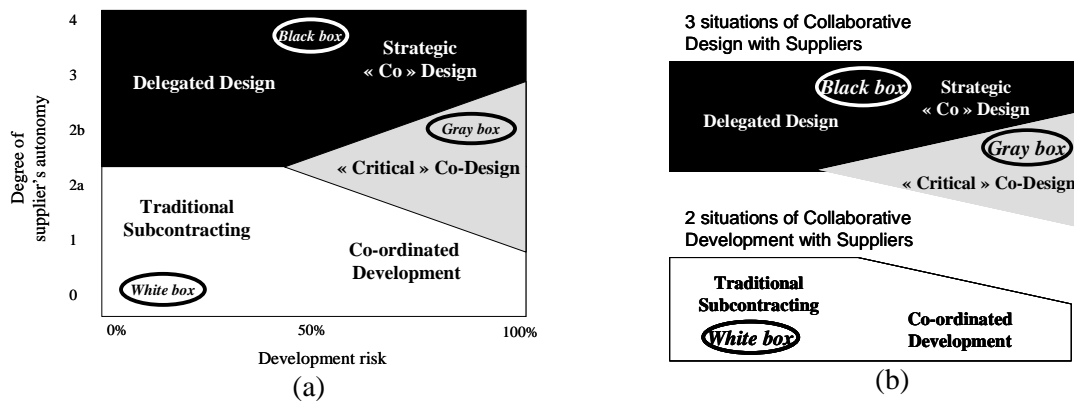


Figure 1. (a) Supplier Involvement Portfolio (Calvi and Le Dain, 2003) - (b) Both exclusive natures of collaboration with suppliers in NPDP

The authors defined five types of customer/supplier involvement in collaborative NPDP associated with different combinations of the two previously identified dimensions.

When the level of autonomy of the supplier is low (levels 0 to 1 on the vertical axis), the relations are generally described as *white box* by Monczka and Trent (1997). In this case, Calvi and Le Dain (2003) defined two types of relations according to the level of development risk associated to the project: **traditional subcontracting** characterised by a low development risk and **co-ordinated development** characterised by a high *systemic and timeline risk*. In both these situations, the outsourced products are mainly simple parts, whose design remains internalised. But with a **co-ordinated development**, due to the nature of the development risk, the product design activity performed by the customer and the process design activity realized by the supplier must be coordinated to obtain effective product/process integration in the building of the final product solution.

If the autonomy of the supplier is high (*black box*), the results of the exploratory survey carried out by the authors invite us to distinguish two types of relationships, in accordance with the risk related to the development of the delegated product: the **delegated development** (levels 2b to 4 on the vertical axis) and **strategic co-design** (mainly level 4 on the vertical axis). In both cases, the supplier carries out the concept design and the development of the outsourced component. But in **strategic co-design**, the high level of risk requires a great amount of communication with the supplier in order to clarify needs and to monitor the evolution occurring throughout the project.

Lastly, the authors qualify as **critical co-design** (levels 2a to 3 on the vertical axis and risk greater than 50% on the horizontal axis) the situation where neither the customer nor the supplier possesses the knowledge and the ability to completely execute the product design in house. The greater the development risks, the more the customer will try to promote and manage the collaboration between both its own and its supplier's project teams. This reasoning thereby explains the triangular nature of the conceptual matrix that we proposed.

This typology is focused on the content of the supplier involvement situations through the design capability of each partner and the nature of the dominant risks. In analysing how customers involve their suppliers in design process, several authors (Bonnaccorsi and Lipparini, 1994; Twigg, 1997; Handfield et al., 1999) have identified the timing of supplier involvement in the product development process as a further-important dimension. Indeed Twigg (1997, p9) highlighted that: "An important element of outsourcing design and development to suppliers is to understand the content and the timing of their participation". (Hartley et al., 1999) stressed that suppliers should be involved at an early stage of the NPDP, others have pointed out that the timing of involvement depends on the intrinsic characteristics of the relationship (Kamath and Liker, 1994; Wynstra and Ten Pierick, 2000). We hold the

view that there is a close link between the extent of the supplier's know-how and the timing of his involvement in NPD.

Thus, we propose to extend the previous *Supplier Involvement Portfolio* to incorporate the interaction between design and/or manufacturing know-how of suppliers and timing of supplier involvement. For that, according to the vertical axis of the *Supplier Involvement Portfolio*, we distinguish two exclusive kinds of collaboration with suppliers in NPD (Figure 1b):

- **Collaborative design**, composed of *delegated development*, *strategic co-design* and *critical co-design situations*,
- **Collaborative development** composed of *traditional subcontracting* and *co-ordinated development situations*.

Both these collaborations are exclusive because the role played by the supplier in customer design activities is radically different as described below. Figure 2 illustrates a simplified view of both collaborations through the various stages of a product development process.

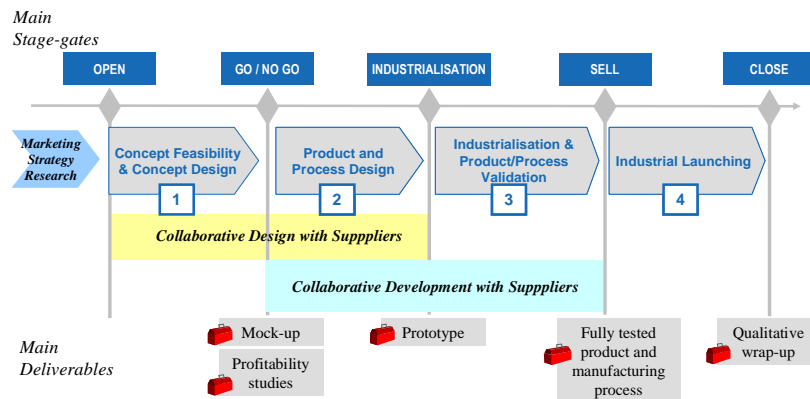


Figure 2: Collaborative Design versus Collaborative Development with Suppliers

- *Collaborative Development with suppliers*: In this case, all design activities are handled by the customer but there is a joint development work with suppliers. The supplier may be consulted at the design stage (stage 2 in Figure 2), according to the need of the customer, to provide his process and manufacturing know how with regard to the dimension of the part, the choice of raw material, etc. (level 0 to 1 on the vertical axis, Figure 1). Nevertheless, the major role of the supplier does not come into play until the industrialisation stage (stage 3 in Figure 2). Dumas (1988) referred to these contributors as “*silent designers*”. Thus, in *collaborative development with suppliers*, the timing of the supplier's involvement refers to both the following issues: the stage where the supplier plays an active role i.e. he is responsible for the results of the industrialisation and/or manufacturing process of the supplied part, and the stage where the supplier plays the role of a *silent designer* i.e. he only gives an informal input to permit his customer to conduct its design activity. In practice, this input often occurs earlier in the process than the contractual supplier involvement stage. For example, a common situation of *co-ordinated development* experimented by our industrial partners concerns the relationship with their suppliers of plastic injection moulding. The latter have expertise on how a plastic part can be manufactured. During the *product/process design* phase, they contribute to the customer's design activity by giving their tacit process knowledge, but the drawings are still supplied by the customer.

- *Collaborative Design with suppliers*: In this case, the supplier has a real responsibility within the design of the customer's product. Indeed, the customer provides functional requirements (performance, interface requirements, space constraints,...), and the supplier takes responsibility for the supplied item from the design to the manufacturing ramp-up (level

2a to 4 on the vertical axis). A similar concept is the “*drawing approved parts*” proposed by Asanuma (1989) in his classification of outsourced parts in the Japanese automotive industry. The timing of supplier involvement depends on the complexity and the criticality of the supplied item (Monczka et al., 2000): the supplier of complex and critical items is already integrated during the concept stage (*strategic co-design* and *critical co-design*), and the supplier of simple and less critical items is not involved until the product and process design stage (*delegated development*). Thus, in *collaborative design with suppliers*, the timing of involvement essentially refers to the stage at which the supplier plays an active role in the NPD process.

The focus of our research is to find how to evaluate the expected results of the supplier in *collaborative design situations*?

2.2. Suppliers’ evaluation in collaborative design: From selection to performance point of view

The supplier evaluation process is commonly clustered under two headings (Le Dain, 2006): the supplier ability evaluation and the supplier performance evaluation. Within *collaborative design*, the objective of both evaluations is the following.

- The supplier ability evaluation aims at assessing the supplier’s capability to innovate and to co-design integrating his know-how and resources into the NPDP implemented by the customer. This evaluation is performed *prior to* the setting-up of the collaboration,
- The Supplier Performance Evaluation (SPE), performed during and after the collaboration, aims at assessing the supplier’s real contribution to a specific project.

A review of literature on both aspects of supplier’s evaluation is given in the two following tables.

Authors	Focus	Nature of the study	Finding and conclusion
Elram (1990)	Developing additional factors that should be considered in the selection of supply partners.	Literature review + case study (8 purchasing representants)	Longer term and more qualitative factors (included in these categories: Financial issues, organizational culture and strategy issues, technology issues...) supplement the more traditional factors in developing strategic partnerships with supplier. There is no single model that fits every situation.
De Boer, Van der Wegen and Telgen (1998)	Proposing and illustrating a decision model for supplier selection that is based on the outranking approach.	Literature review Conceptual + applicative example	Outranking techniques may be a useful additional tool for the problem of supplier selection. Because (1) both quantitative and qualitative criteria can be accommodated ; (2) it enable to apply compensatory decision rules ; (3) it is flexible
Handfield, Ragatz, Petersen and Monczka (1999)	Studying supplier selection and timing of supplier involvement	Survey	Identification of supplier selection criteria and timing of supplier integration depending on the kind of product that has to be developed and on the technology risks.
De Boer, Labro and Morlacchi (2001)	Presenting a review of decision methods for supporting the supplier selection process.	Literature review	Most attention has so far been paid to the choice phase in the supplier selection process. The phases prior to this choice phase (problem definition, criteria formulation and qualification) have received far less attention from researchers in operations research or purchasing and supply.
Petroni and Panciroli (2002)	Measuring the impact of technological and managerial innovative capabilities on critical performance factors (C, Q, D, flexibility) for different type of supplier	Survey (198 suppliers in the food packaging machinery industry in northern Italy)	The level of investment in technology and the acquisition of specific managerial capabilities are, to a large extent, a determinant of supplier–customer interdependence.
Dulmin and Mininno (2003)	Investigating the contribution of a multi-criteria decision aid method to supplier final selection	Case study (1 mid-sized Italian firm in public road and rail transportation industry)	In spite of several studies about the importance of co-design and the integration of suppliers in the new product development, vendor rating is still focused on productive-logistical performance and not, whereas it should be necessary, on supplier's co-design capabilities. Crucial evaluation criteria are highlighted.

Table 1 (continued)

Authors	Focus	Nature of the study	Finding and conclusion
Huang, Mak and Humphreys (2003)	Proposing a new model of customer–supplier relationships with special interest in their new product development processes	Conceptual	Ideally, a supplier with the highest <i>Satisfaction Index</i> , highest <i>Flexibility Index</i> and lowest <i>Risk Index</i> is the best candidate. However, it may be difficult for one supplier to outperform other suppliers in all these three indices. Therefore, trade-offs are necessary. When the <i>Confidence Index</i> of a supplier is maintained a high level for a sufficient period of time, a long-term partnership may be considered with this supplier.
Humphreys, Wong and Chan (2003)	Developing a decision support tool which should help companies to integrate environmental criteria into their supplier selection process	Conceptual	In the long term, environmental issues will become an important factor for a company to consider. Integrating environmental management techniques along the supply chain is an appropriate method of enhancing the environmental performance of an industry
Goffin, Lemke and Szwajczewski (2006)	Giving the specific attributes of "close" supplier–manufacturer relationships	In depth interviews (39 purchasing managers with a technique from psychology)	Only certain suppliers should be selected for the development of partnership-like relationships. The selection criteria should be based on both the components involved and the supplier's competences (particularly their capability to contribute to new product development and special products)
Chen, Lin and Huang (2006)	Presenting a decision-making tool for supplier selection decision	Conceptual	In general, supplier selection problems adhere to uncertain and imprecise data. So, the use of linguistic variables is highly beneficial when performance values cannot be expressed by means of numerical values.
Schiele (2006)	Proposing criteria to identify innovative suppliers: specialized, technically competent, proximity of the buyer, trusted and intensive relationship	Conceptual	8 criteria to help identify innovative supplier are given: specialised firms, own development capability, firms engaged in collaborative venture, relationship based on trust and commitment, joint improvement program, geographical proximity, important buyer, history of collaboration with the buyer.
Huang and Keskar (2007)	Presenting a mechanism to integrate strategic thinking with quantitative optimization in order to make sound and effective decisions on supplier selection.	Conceptual	Selection of the best suppliers must be driven by a firm's supply chain strategy, which is a high-level management decision. The large amount of decision-making methodologies presented in the literature is basically variations of optimization methods. However, the more important issue is how to make sure that these methods are used effectively so decisions made indeed lead to the improvement of a firm's profitability.
Humphreys, Huang, Cadden and McIvor (2007)	Proposing a mechanism for evaluating supplier involvement during product development	Case study (1 multinational telecommunications company)	There have been a number of benefits to both buyer and supplier organizations by establishing clearly defined design criteria. In order to obtain maximum strategic benefit from the integration of the supplier, both parties need to share objectives and have complementary future technology plans.

Table 2

A chronological review of the literature on supplier performance evaluation

Authors	Focus	Nature of the study	Finding and conclusion
McCutcheon, Grant and Hartley (1997)	Examining how the designers perceive supplier involvement in the design of critical technology.	Survey (160 firms in assembly industries)	When involving suppliers in collaborative project, designers seem to pay more attention to the cooperativeness of the supplier than to its technical competence.
De Toni and Nassimbeni (2001)	Presenting a framework for the analysis and measurement of the supplier's co-design effort	Literature review + Tests with 16 suppliers of 1 Italian company in Industrial Automation	Proposed criteria are based on the techniques and methodologies carried out by the supplier in the 3 main NPD activities (Product concept and functional design; Product structural design and engineering; Product design and engineering)
Araz and Ozkarahan (2007)	Describing a supplier evaluation and management methodology for strategic sourcing	Conceptual	The methodology should integrate 3 elements to evaluate and manage supply base and to select strategic partners in product development (supplier evaluation system, supplier sorting system, supplier management system) In supplier evaluation phase, the criteria to be selected for evaluation of suppliers should emphasize long-term relationship and concurrent product development.

From this overview of literature on supplier evaluation (table 1 and 2) in NPDP, we highlight the four following issues:

- Limited attention in the literature. Although most authors (Wynstra et al., 2003; Bidault et al., 1998; Goffin et al., 2006; Humphreys et al., 2007) consider the supplier selection as a key process in the Early Supplier Involvement (ESI) in NPDP, it is surprising that this process should receive only limited attention in the literature. Moreover, most of the papers which are related to the development of methods or tools supporting supplier selection don't pay attention to the relevance of the selected criteria used in their models (De Boer et al., 1998; 2001; Dulmin and Mininno 2003).. In addition, selecting suppliers with requirements of innovativeness and cooperativeness has to follow different criteria than the selection of such suppliers whose product is only differentiated by its price (Ellram, 1990; Petroni and Panciroli, 2002). However, as Schiele (2006) highlights, to day neither research nor practice have so far offered conclusive tools helping to identify innovative suppliers.
Finally, it is even more surprising that the ESI literature should not refer to the supplier's performance process and consequently research in this topic is still in its infancy.
- Difference between selection (*prior to*) criteria and performance (*during and after*) criteria. It is important to understand the difference between both these evaluations to define relevant criteria: The first one refers to the evaluation of the supplier's *means* and the second refers to the evaluation of *the results* (Le Dain, 2006). For both these evaluations, the criteria proposed to evaluate the supplier's innovativeness, for example, are different:
 - (1) In order to select the suitable supplier, we need to evaluate his innovative capability not only through their technological competencies in product/process innovation performed in the previous projects, but also their innovation-supporting managerial competencies (technological scanning, project management competence...)
 - (2) In order to measure the innovative performance of the supplier, we can evaluate the willingness of the supplier to suggest different product (and/or process) solutions in order to meet the customer's needs, and/or his ability to perform an appropriate re-use of existing solutions...
 However, in most papers, this distinction between *means* and *results* evaluation is not clearly defined.
- A one shot performance evaluation. Most of the Supplier Performance Evaluation models are based on a sole evaluation per project commonly performed at the end of the project. In practice, the development time of a new product varies from one to five years. Thus, it seems to be useful to evaluate the supplier at each main milestone in order to effectively manage the supplier throughout the project.

3. Research methodology: two stages multiple case studies

The performance evaluation model presented in this section stems from a research program started in 2001 (Calvi et al., 2001) on the wide topic of supplier's integration in NPDP. Our purpose was to build up "*actionable knowledge*" (Schön 1983) i.e. knowledge that can serve the purpose of action. For Argyris (1993), the aim of any theory of managing is to produce generic propositional statements or principles called *genericizations* that are actionable by managers in the organization's daily operations. In turn, as managers use such *genericizations*, it enables them to test the external validity of the academic corpus. So an actionable theory requires to inform the decision-makers about what is likely to happen under given circumstances but also to tell them how to set-up the suitable conditions for the success of such action. This objective imposes a methodology with a tight link between researchers and practitioners in order to co construct the generic models of the research.

The study is based on qualitative multiple case studies addressing both the customer and their suppliers involved in a collaborative design experience. As Bonoma (1985) argued that

methodology should become an acceptable form of research when the focal phenomenon cannot be easily studied outside its natural setting, and cannot be readily quantified. This approach should match the complexity and comprehensiveness of the focal phenomenon: the supplier integration and his contribution in NPDP. Yin (1994) pointed out, while studying phenomena that take place in contexts full of meanings, that there will always be too many variables to take into account for the number of observations made. Consequently, the application of standard survey may not be appropriate. In-depth interviews have been recognized as particularly useful for studying supplier relationships (Mc Cutcheon and Stuart, 2000). In our research, we adopted the case study method collecting not only data from the key managers of both the customer and supplier companies, but also using archival data.

Our research methodology includes two consecutive phases: a pilot study and a main study. This two-phased research strategy was considered useful, because we aimed at getting a better understanding of the phenomenon before launching a main study: the PRAXIS research project - involving industrial partners. Figure 3 describes the link between the two phases.

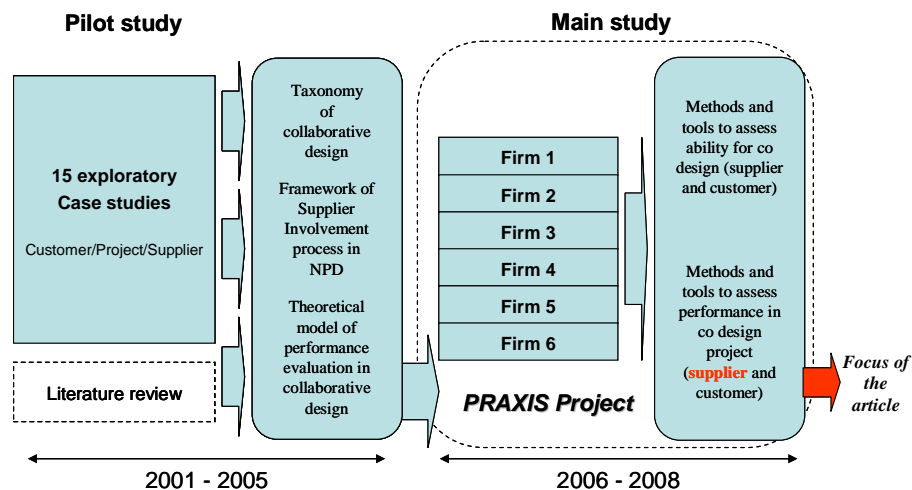


Figure 3: The Research Methodology

The pilot study consisted in conducting 15 case studies during the year 2001. The sample represents a wide range of French Industries (Electronics, Electrical appliance, Automotive and industrial equipment industries). We chose firms owning up as experimented in collaborative design. In these exploratory case studies, we used a semi-directed interview guide aiming to describe one particular experience of the customer-supplier relationship in a new product development project. The interviews mainly involved purchasing and/or technical leaders on the project team. The interviewed company was asked to select one experience concerning supplier involvement in an NPD project. In several cases, interviews were equally conducted with the supplier involved. Through this inductive approach and a broad literature review, three main propositions have emerged. First, we suggested a framework of Supplier Involvement process in NPD which specifies how to manage the supplier involvement *prior to*, *during*, and *after* the development of a new product (Calvi et al., 2003). We also proposed an original taxonomy of the situations covered by the wide term of collaborative design. Finally, we devised a theoretical model of performance evaluation in collaborative design adopting a grounded theory approach where “the researcher begins with an area of study and allows the theory to emerge from data” (Strauss and Corbin, 1998, p 56).

The main study - PRAXIS research project - was born from the setting-up of a focus group of six enterprises interested in benchmarking and getting practical advice on the topic of “how to evaluate suppliers’ performance in collaborative design?” The objectives of the PRAXIS project have been jointly defined between researchers and practitioners. The PRAXIS project

aims at proposing methods and tools on the one hand to assess the ability of both partners (customer and supplier) to co-design and on the other hand to evaluate the performance of both partners throughout a product development project. A PHD thesis funded by PRAXIS industrial partners started in January 2007. It is dedicated to three tasks: the animation of this expert group, the development of a supplier performance evaluation tool and the setting up of this tool in partner's team project. After collecting their comments, we will adapt our previous model to each context using a contingency approach. For that, we have adopted a research action approach integrating the researcher within the project team of each company. This was appropriate because an intervention was required to test the tools in a real-life setting and to obtain feedback for their improvement. This ongoing research must provide an integrated view of the supplier's performance evaluation issue in NPDP.

4. Building a Supplier's Performance Evaluation model in collaborative design

In this paper, we focus on the evaluation of the supplier's performance in collaborative design. After explaining how we structured our model, we will present the retained criteria.

4.1. Why building a Supplier Performance Evaluation in collaborative design?

Nowadays practices have changed and in industrial sectors where suppliers contribute in a large amount to product value, customers use to select suitable suppliers not only on their cost, product quality and delivery reliability but also on their *high potential contribution to the innovativeness of the firm* (Schiele, 2006). However, a selected supplier which was judged capable of answering the customer's expected requirements could fail to collaborate successfully *in situ* during the project. For this reason, customers have to regularly evaluate the effective results of the supplier compared to their expected requirements. Here, there is a lack either in practices or in theory in the field of supplier performance evaluation in NPDP.

For the focal firm, the evaluation of the supplier's performance within the framework of a New Product Development Project (NPDP) may be used in three different ways: (1) on a short-term basis, to identify the critical issues and deliver co-designed solutions for joint implementation, (2) on a middle-term basis, to continuously improve the performance of the suppliers and (3) on a long-term basis, to streamline the suppliers panel for future projects. From a suppliers perspective, such evaluation could enable them to clearly identify the performance criteria expected by the customer and thus, to dynamically improve their organisation in order to evolve from "standard supplier" to "innovative design-key supplier".

4.2. Structure of the model

The model suggested here is intentionally generic in order to take into account the different situations of *collaborative design* with suppliers. This model is based on the two following axes (Figure 4):

- ***The stage of Supplier Involvement in a NPDP.*** The supplier development effort must be evaluated throughout the project with criteria adapted to each stage. As an illustration, the nature of the performance of a sub-system supplier involved at the concept design stage evolves according to the phases of the project. For instance, in cost matter, the expected performances are: (a) the relevance of cost estimation in phase 1, (b) the compliance to the target cost in phase 2 and (c) the price stability in phase 3. Thus, the measurement of the performance must be adapted in order to take into account the specificities of each situation. To build our SPE model, we considered only the three first stages of the product development process because the expected supplier's performance at the phase of industrial launching is more of a classical industrial performance than an engineering performance.
- ***The type of Customer Requirements expected during the collaboration.*** We have identified four main requirement areas expected by the customer in collaborative design

with suppliers:

- Know-how on the delegated product,
- Know-how on the delegated process,
- Project management skills,
- Relational skills.

This set of four requirement areas is introduced on the basis of our pilot study. In order to take into account the various situations, we distinguished know-how related to the product from know-how related to the manufacturing process. Indeed, a supplier who is in charge of the product and process design for a component can have different levels of performance on both these types of activities. For a subcontractor, the sole area of performance to measure should be his process know-how. In addition, the stakeholders who will evaluate both these performances are not generally the same ones in the customer firm (Le Dain, 2006). Indeed, the criteria related to the product are usually evaluated by the design-team whereas the criteria related to the process are evaluated by the industrialisation-team.

In terms of relational and project management skills, these one are often evaluated during the suppliers' selection in collaborative design. Spekman and Carraway (2006) like Lindgreen, Vanhamme and Wouters (2006) affirmed that the organisational competence of the suppliers (ability to be organised in a project team, existence of a cross-functional team, reactivity ...) is a fundamental criterion of selection because it strongly affects the performance of the co-design activity. According to our industrial partners, it is relevant to evaluate these two aspects not only during the selection process but also throughout the project because a supplier can be assessed as "good" *ex ante* but prove non-powerful *in situ*.

Finally, for each combination of these two axes, we proposed the *effectiveness*, *efficiency* and *pro-activity* criteria to evaluate the supplier performance in collaborative design (Figure 4) following the advice of Mentzer and Konrad (1991), who claimed that a common definition of the performance measurement is the evaluation of effectiveness and efficiency of completing a given task and Le Dain (2006) who proposed a third dimension - pro-activity - besides the first 2 dimensions.

- *Supplier effectiveness*: A supplier is considered as *effective* if his results meet the objectives fixed by the customer. For example, the respect for the classic customer triptych requirements - cost, product quality and delivery - corresponds to the *effectiveness* dimension of the performance for a supplier.
- *Supplier efficiency*: A supplier is considered as *efficient* if he is able to use projects resources in an appropriate manner and hence achieve the expected results. These project resources should be either organisational competencies (project organisation, cross-functional team ...) or technical competencies (concurrent engineering methods and as value analysis, CAD tools, numerical simulation tools, FMEA ...).
- *Supplier pro-activity*: We define the supplier *pro-activity* as the supplier ability to improve by itself and consequently to pull forward the customer in delivering more than the minimum requirements. For example, a supplier involved in the concept definition stage must be able to challenge the customer specifications by suggesting minor modifications to the customer, which would produce significant benefits in terms of cost, quality and/or time.

What should be the right mix of *effectiveness*, *efficiency* and *pro-activity* to evaluate supplier performance in NPDP? To enlighten these issues we can mobilise Ouchi's theory of governance mechanisms (1980). Indeed, according to this theory, the control of the relation by the only criteria of effectiveness is reserved for situations characterized by a small ambiguity in the performance measurement. Thus, in the case of *traditional subcontracting* (Figure 1), the criteria of effectiveness could be sufficient. However, in the cases of customer/supplier relationships in the design stage, it is not enough to define the customer's

requirement towards suppliers using the sole criteria of “effectiveness”. For example, in the case of a *critical co-design*, one typical requirement of the customer is that the supplier should spontaneously share his expertise to solve problems that have not been necessarily identified at the beginning of the project. Thus, it seems relevant to couple together this measure of efficiency with the other two dimensions of the performance in accordance with the degree of suppliers’ implication in the design process.

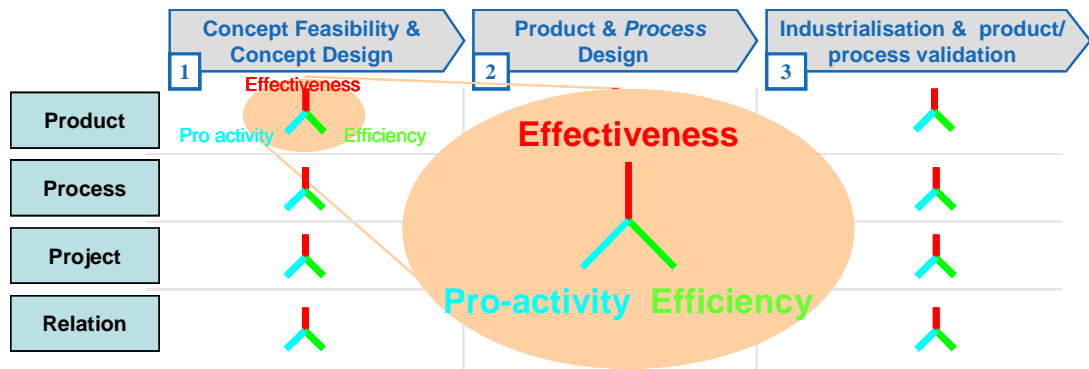


Figure 4. Structure of the Supplier Performance Evaluation model

4.3. Criteria specification

Figure 5 presents the criteria suggested in our model of supplier performance evaluation in collaborative design.

	1 Concept Feasibility & Concept Design	2 Product & Process Design	3 Industrialisation & Validation
Product	<ul style="list-style-type: none"> 1- Compliance with contractual product requirements 2- Reliability of mock-ups 3- Quality of cost’s estimates and compliance with target cost 4- Participation in the definition of needs 5- Proposition of a range of solutions 6- Proposition of innovative solutions 7- Appropriate re-use of existing solutions 8- Mastery of the methods and tools of the design (value analysis...) 9- Management of second tier supplier (if necessary) 10- Ability to challenge the contractual specifications 11- Ability to implement environment-friendly procedures 	<ul style="list-style-type: none"> 1- Compliance with contractual specifications 2- Reliability of prototypes 3- Compliance with target cost 4- Proposition of a range of solutions 5- Proposition of innovative solutions 6- Appropriate re-use of existing solutions 7- Mastery of the methods and tools of the design (product FMEA ...) 8- Management of second tier supplier (if necessary) 9- Ability to challenge the contractual specifications 10- Ability to implement environment-friendly procedures 	<ul style="list-style-type: none"> 1- Compliance with contractual specifications 2- Reliability of pilots, robust pilot run 3- Price stability 4- Control of the risks connected with the supplied product 5- Verification of products 6- Ability to solve technical problems 7- Ability to cut product cost
Process	<ul style="list-style-type: none"> 1- Proposition of a range of process solutions 2- Compliance with contractual specifications 3- Quality of estimated investment figures 4- Proposition of innovative manufacturing technologies or processes 5- Appropriate re-use of existing manufacturing processes 6- Management of second tier supplier (if necessary) 7- Ability to define the supply chain 	<ul style="list-style-type: none"> 1- Proposition of a range of process solutions 2- Compliance with contractual specifications 3- Proposition of innovative manufacturing technologies or processes 4- Appropriate re-use of existing manufacturing processes 5- Knowledge of product/process integration 6- Definition of the supply chain 7- Management of second tier supplier 	<ul style="list-style-type: none"> 1- Compliance with the investment budget 2- Compliance with contractual specifications 3- Control of the risks connected with the manufacturing process 4- Relevance of manufacturing process expertise 5- Supply chain performance 6- Procurement performance
Project	<ul style="list-style-type: none"> 1- Compliance with contractual delivery dates 2- Mastery of its own product development process 3- Method for managing the modifications with impact 4- Risks’ anticipation 	<ul style="list-style-type: none"> 1- Compliance with contractual delivery dates 2- Mastery of its own product development process 3- Method for managing the modifications with impact 4- Risks’ analysis 	<ul style="list-style-type: none"> 1- Compliance with contractual delivery dates 2- Risks’ mastery 3- Mastery of its own product development process 4- Method for managing the modifications with impact
Relation	<ul style="list-style-type: none"> 1- Responsiveness to requests from the customer 2- Reliability of information exchanges 3- Quality of responses to Request for Quotation 4- Availability of the supplier relevant staff 5- Diligence with which services are performed 6- Similarity of mindsets 7- Ability to commit to agreements 8- Transparency 	<ul style="list-style-type: none"> 1- Responsiveness to requests from the customer 2- Reliability of information exchanges 3- Quality of responses to Request for Quotation 4- Availability of the supplier relevant staff 5- Diligence with which services are performed 6- Similarity of mindsets 7- Ability to commit to agreements 8- Transparency 	<ul style="list-style-type: none"> 1- Responsiveness to requests from the customer 2- Responsiveness to non-conformity 3- Reliability of information exchanges 4- Availability of the supplier relevant staff 5- Diligence with which services are performed 6- Similarity of mindsets 7- Ability to commit to a progress plan 8- Transparency

Figure 5. Generic model of supplier performance evaluation in collaborative design

In order to take into account the different situations of collaboration, a specific set of criteria has been specified for each combination of the two axes. For that we applied the following rules:

- The definition of the same criterion can be declined differently in accordance with the customer’s requirements during the project. As an illustration, Figure 6 illustrates for each phase the variation of the definition of two quality criteria throughout the NPDP.



Figure 6. Variation of criteria of effectiveness during the project

- The nature (effectiveness/efficiency/pro-activity) of the same criterion can evolve during the project. As an illustration, Figure 7 presents the evolution of the criterion related to the risk. Thus, a supplier integrated in phase of *feasibility and definition of the concept*, which has demonstrated an ability to anticipate risks from this phase, will be considered as *pro-active*. The supplier shares a preliminary risk analysis with his customer and so can improve the customer’s concept definition. In phase of *Product & Process Design*, the supplier is in charge of the risk analysis. The supplier has demonstrated his excellent understanding of the analysis method used in order to control the risk. Thus, the criterion becomes an *efficiency* criterion. Finally, in phase of *Industrialisation*, the customer expects the mastery of the risk of his suppliers. The supplier has demonstrated his willingness to implement pre-defined risk control measures within a short time frame. Thus, in this case this criterion becomes a criterion of effectiveness.

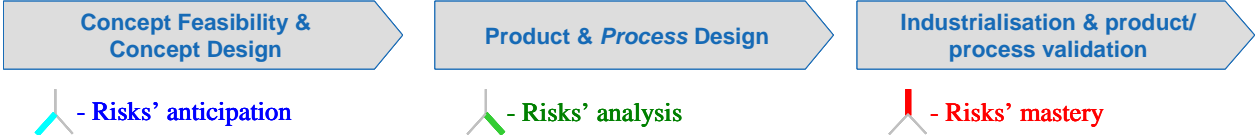


Figure 7. Evolution of the criterion related to the risk

4.4. Criteria presentation

In this section, we present the main criteria proposed in the Supplier Performance Evaluation Model and the reason for their choice based on the findings of the literature review (table 1 and 2).

4.4.1. Criteria of effectiveness

For product and process performance items, quality and cost are both the classical effectiveness criteria. As we previously said, the definitions of these criteria evolve along the phases. In a context of NPDP, the delivery reliability is a one aspect of management project performance of the supplier and is evaluated through the *compliance with contractual delivery dates*.

When a customer involves a supplier at the beginning of the concept feasibility and definition stage, most information is imprecise and the customer expects the supplier’s help to

clarify the need. In this case, the *participation* of the supplier *in the definition of the concept* and his *ability to propose a range of solutions* are considered as effectiveness criteria.

Prahinski and Benton (2004) affirmed that *the supplier's commitment should influence the supplier's performance*, even if *empirical research that directly measures the impact of supplier's commitment on performance was not found*. They argue that *when a supplier is committed to a buying firm, the supplier will want to ensure the continued success of the business relationship and therefore, meet and/or exceed the needs of the buying firm*. We declined this commitment in terms of reactivity (*responsiveness to customer's requests, responsiveness to non-conformity*) and of motivation (*reliability of information exchanges* as well as the *quality of responses to Request for Quotation* during the project).

4.4.2. Criteria of efficiency

We classify the selected criteria along the two axes of efficiency which seem relevant to evaluate the appropriate use of the supplier concurrent engineering practices necessary to reach the expected results (Le Dain, 2006):

- Relevance of the supplier's expertise.

Finding innovative products with respect to cost and time constraints is a major stake in NPDP. To face this challenge, the customer not only expects *proposition of innovative solutions* from the supplier (Von Corswant and Tunaly, 2002; Sobrero and Roberts, 2002; De Toni and Nassimbeni, 2001) but also an *appropriate re-use of existing solutions* (Hartley et al., 1997). Thus, the relevance of the supplier's expertise refers to his ability to supply "a suitable innovation". De Toni and Nassimbeni (2001) emphasize that this supplier's expertise also refers to the specific use of "*concurrent engineering*" *methods and tools* (value analysis, product FMEA and process FMEA ...).

- Aptitude for collaborating with the project team.

This goes through the *mastery* by the supplier *of his own product development process* (resources allowed, milestones, cross functional team, consistency of development schedules, management of different configurations and modifications,...). The supplier and the customer would have to agree on a mode of project management since the beginning of their collaboration and then the supplier would have to respect the commitments. The *availability of the supplier's relevant staff* and *the diligence with which services are performed* also contribute to the successful fulfilment of the project.

In an internationally-extended design context, the criterion of *similarity of mindsets (industrial and/or cultural)* becomes important to avoid the conflict management culture. Moreover, we agree with Lam and Chin (2005) when they highlight that "with the mindset that certain conflict could be beneficial, clients and suppliers are apt to express their judgmental differences for improving decision making".

4.4.3. Criteria of pro-activity

The management of the supply chain of the supplier is an important task for the success of a project (Von Corswant and Tunaly, 2002). As 75% of the defects that entail repairing or substituting a component, concerned parts that had been produced by second tier suppliers (Follis and Enrietti, 2002), it is relevant to measure the supplier's ability to bring in *any tier-supplier* that it deems necessary to successful co development project.

As for the cost, the supplier's pro-activity consists in **challenging the contractual specifications** in phase 1 and 2, then in seeking how to **cut the cost of parts and investments** in phase 3. The customer also appreciates when the supplier **contractually commits to a progress plan** to obtain a better productivity and secured procurements.

Mc Cutcheon et al. (1997) carried out a study in order to examine the perceptions of new product designers about the component suppliers involved in a NPDP. They concluded that “the cooperativeness of the supplier was probably more influential than his technical competence in influencing the willingness of the product designer to bring the component supplier into future development projects”. The dimensions of *efficiency* and *pro-activity* aim at evaluating with objective criteria this expected *cooperativeness* of the supplier.

Each criterion must be graded from 0 to 5. Furthermore, to facilitate the grading, we specify for each criterion the exact meaning of the three performance levels – maximum (5/5), intermediate (3/5) and minimum (0/5).

5. Conclusion and implications

One of the main starting points for our study was the limitations of existing research in providing a broad and comprehensive definition of what is an efficient co-design supplier. The proposed model, based on the identification of four performance areas combined with three involvement stages, provides an improved conceptualization of the supplier performance understanding in an extended product development context. The other important notion implicitly included in our model is that collaborative design is not limited to managing the supplier’s involvement in single development projects. To perform innovation and development activities, the customer firms must be able to upgrade the *relation - specific skill*^v of their key suppliers from *collaborative development* to *collaborative design* responsibilities. To create a real dynamic of capitalization between the different NPDP, the firms must improve their understanding of what should be an effective collaboration in order firstly to drive the performance and then to reduce the perceived risks associated to this practice.

As stated in the description of our research methodology, our purpose was to build up *actionable knowledge*, so we can point out some managerial implications of our study. Firstly, the generic model presented in Figure 5 can be used throughout a product development project as an assessment tool to have an objective measure of the co-design effort of suppliers in NPDP. The suggested model allows the customer to identify critical questions and show where improvements could be made in implementing co-defined solutions with the supplier as recommend by Humphreys et al. (2004). In addition, the tool enables the supplier to clearly clarify the performance criteria expected by the customer of an innovative partner. This tool will serve as a basis for defining the continuous improvement strategy needed to guarantee the success of the collaboration. Thus, some workshop sessions between our six PRAXIS industrial partners and about ten of their suppliers were organised to take into account the supplier’s opinion about the relevance of our proposition. Their interest for the model has been high due to the ambiguous nature of the performance in collaborative design.

This research explores a relatively new area of supplier performance in collaborative design and has a number of limitations that we have identified. Firstly, the industrial partners of PRAXIS have joined the project because they had not had extensive experience in collaborative design and had expressed willingness to improve their practices. Our model, co-constructed with these firms, is also the reflection of this contingency situation. A recommendation for future research would be to carry out investigations in other industrial contexts in order to test the generic property of our model.

A second limitation of our research is that in the case of a relationship marked by a strong collaboration, it is relevant to evaluate, beyond the only performance of the supplier, the performance of the whole relationship. To do, we plan to adapt our model to the evaluation of the client’s effort to co design with suppliers.

6. Thanks

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ⁱ In this initial message of the RBV theory, the differences of firm performances are fundamentally due to heterogeneity on resources and capabilities that are owned in house.

ⁱⁱ This project is supported by the Business & Innovation Centre of Haute-Savoie (Thésame). It gathers researchers in Engineering Design (G-SCOP – Scientific Manager of the project) and in Management Science (CERAG and OEP Prism), a professional syndicate (Udimec) and 6 French industrial partners (Biomérieux, Bosch RexRoth Fluidtech, Salomon, Schneider Electric, SNR Roulement and Somfy).. This project began in January 2006 for 4 years.

ⁱⁱⁱ For the authors (Calvi and Le Dain 2003) the levels from (0) to (4) are:

- (0) The supplier is responsible for setting up the manufacturing process. He provides input in customer's product design by sharing information about his equipment and process capabilities and production scheduling,
- (1) The supplier is responsible for the setting up the industrialization and production processes based on the drawings supplied by the customer. He provides feedback on customer's design including suggestions for cost or quality improvements,
- (2) On the basis of functional specifications, the supplier is responsible for the detailed design, the testing and the setting up the production and assembly processes,
- (2a) The customer keeps the intellectual property rights of the component and pays design fees to the supplier,
- (2b) The supplier holds the intellectual property rights of the component and is held legally responsible,
- (3) The supplier has the full responsibility from concept to manufacture for the design of an entire part. The supplier maintains the intellectual and industrial property rights,
- (4) The supplier is responsible for the global design (concept, feasibility studies, supply chain organisation), the detailed design (product and process), the testing of global and detailed design and the setting up the production and assembly processes of a complex subsystem.

^{iv} The six combinatory types of development risk identified by the authors are the following: (1) Systemic link between supplier component and final product performance, (2) Differentiation Produced by Component, (3) Component Development Timeline, (4) Newness of technology, (5) Weight of component cost for the final product, (6) Internal complexity.

^v In the classification build by Asanuma (1989), our article gives a tool to improve what he calls X1 abilities of the supplier (Table III,p24), i.e. his ability to propose improvement on part design.