Front-Loading Problem-Solving in Co-Development: Managing the Contractual, Organisational and Cognitive dimensions[1].

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“ Front-Loading ” Problem-Solving in Co-Development:
Managing the Contractual, Organisational and Cognitive dimensions.

Abstract: “ Front-loading ” problem-solving is one of the major strategies to reduce development costs and development lead time. In co-development situations, the implementation of such methodologies rises specific questions, due to the difficult partition in responsabilities and skills between the car manufacturer and the supplier, especially when customer and supplier contributions cannot be clearly interfaced in a “ black-box sourcing ” relation. This results in a difficult and permanent debate about design modifications.

The article analyses such a co-development situation in the case of a car manufacturer and its die design and engineering suppliers. The case illustrate how to combine organizational integration (i.e. co-localization, shared development methodologies) with new economic contracting rules which create front-loading problem-solving incentives for the two partners. We compare the economic outcomes of a traditional process with a co-developped project, from the viewpoint of both the customer and the suppliers.

The study demonstrates how co-development played a major role in reducing the number and cost of modifications for the customer. The benefits which suppliers can earn depend on their ability to involve in the project in terms of design and engineering capacity at an early stage. These results generate theoretical outputs which bridge the gap between incentive and contract theories on one side, and cognitive and learning fields on the other.

Key words : concurrent engineering, co-development, contracts, learning, die design.

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Introduction

“ Front-loading ” problem-solving (Thomke et Fujimoto, 2000) is one of the major strategies to reduce development costs and development lead time (Midler, 1995, p 369). In co-development situations, the implementation of such methodologies rises specific questions, due to the difficult partitions in responsabilities and skills between the car manufacturer and the supplier. The problem is particularly important when customer and supplier contributions cannot be clearly interfaced in a “ black-box sourcing ” relation. The result is a difficult and permanent debate about design modifications.

The article analyses such a co-development situation in the case of a car manufacturer and its die design and engineering suppliers. For the car manufacturer, the target is to reduce the number of dies modifications number and thereby the budget, which has a major impact on the global performance of the projects. But on the other side, in the traditional relationship, modifications appear for the supplier as a important complementary revenue. Therefore, the codevelopment efficiency depends on the capacity to combine organisational integration (i.e. co-localization, communication, ...) and adapted shared front-loading methodologies with new economic contracting rules which create front-loading problem-solving incentives for the two partners.

This article analyses a case experimenting such a combination of new organizational and contracting co-development practices. It is based on interactive research conducted with an European auto-maker, and of a representative sample of the company’s stamping-tool suppliers (Garel 1999). Following the outsourcing of stamping operations in the early 1990s, this auto-maker, which we will refer to as “X,” wished to evaluate its new partnerships with suppliers. In the context of a study conducted over a period of two years, we were able to crossanalyse the viewpoints of both the customer and its suppliers. In order to assess the profits and losses generated by co-development, we did a comparative study of two successive automotive projects: a *TR (Traditional) project*, conducted without co-development from the late 1980s to the early 1990s, and the following[4], a *CD (Co-Development) project*, pioneered jointly with the tool-makers in the early-mid 1990s. We analysed the performance of four European tool-makers (A, B, C, D) participating in both the TR and CD projects. The field study was conducted from December 1995 to July 1997. We drew on internal data collected from Auto-Maker X and its suppliers (files, reports, notes, etc.); on re-assessments made at our request (submitted by the firms); on interviews (over thirty); and on regular cross-checking carried out by the steering committee of the interactive research.

In the first part of this article, we will analyse the differences in the two studied development processes, by refering to our characterization of the co-development concept. In the second, we present our comparison of co-development performance with traditional design process one. The research was targeted on the development and investment costs. An important characteristic of our methodology is that it reflected not only the car manufacturers viewpoint, but also the suppliers economic vision (the methodology was validated both by the auto-maker and the suppliers). We present the results of this analysis in section 2 .2. As will become apparent, these results substantiate the hypothesis of a “win-win” situation between customer and supplier, although not all suppliers reaped the same benefits. In the third and final section, we discuss our results through an analysis of the advantages accruing from co-development in terms of two variables: supplier engineering skills; and long-term stability of the auto-maker/supplier relationship. This analysis supports the need for systematic

[4] The launching of the second project was two years after the first one

integration into the theoretical design-performance model of organizational, incentive and cognitive factors.

1. Comparison of TR and CD processes on organizational and contract variables.

Many authors have contributed to define the partnership and co-development notions. Consistently with those of those Lamming (1993) and Liker, Ettlie and Campbell, (1995), we will characterize co-development processes in terms of five conditioning factors (Midler, Garel and Kesseler, 1997). The idea being that co-development efficiency is the result of a global coherency of this set of variables.

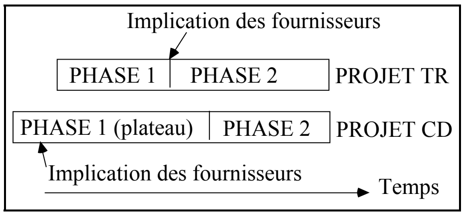
- The early selection of a supplier, based on strategic criteria, for a cooperative endeavor lasting throughout the duration of the development process.

The die tools development includes two phases (see figure 1): phase 1 is a design period and ends in a technical specification freeze of the tool. Phase two is a production period of the tools. For project TR, Phase 1 lasted for 4 months, compared to 18 months for Project CD. Phase 2, on the contrary, was shorter for Project CD. It has been further extended for more recent projects[5].

For CD Project, the customer-supplier relationship was formed at the beginning of phase one, the selection being made on the basis of positive previous experience with the suppliers, and on the customer's long-term strategic objectives. For TR project, this relationship was established only after the technical definition of the new product had been completed, at the end of phase 1, on the result of the cost bidding process.

[5] Time to-market strategies focus on reduction of leadtime between specifications freeze and market introduction.

Figure 1: Co-development and the extended supplier time involvement



- Supplier involvement affecting a broader operational perimeter.

Co-development implies a shift from basic-component supply to transactions involving complete vehicle sub-systems. In the metal-stamping field, assignments to tool-makers are today made by the total lot, and are based on the physical perimeters defining an entire system (for example, all the stamped pieces for a door); whereas, formerly, assignments were made component-by-component and awarded to the lowest bidder. This way, interface problems between individual components (the geometric fit and visual appeal of the body as a whole) are all handled by the same supplier. Figure 2 gives the difference between TR and CD projects concerning components in a lot assigned to major supplier.

Figure 2 : comparison of component assignment to TR and CD suppliers.

Number of components assigned to major supplier / total number of components in the lot	1	2	3	4	5	6	Mean (en %)
Projet TR	3/5	8/50	4/7	6/23	10/12	5/14	46%
Projet CD	5/5	23/32	7/7	12/12	6/8	8/12	85%

- Adoption of joint development methodologies focused on front-loading and learning.

A design process inevitably implies unforeseen problems and modifications not included in the original specifications. The skills which need to be mobilized for a design operation are hard to define and coordinate (Schön, 1983; Nonaka, 1994). It is therefore more important to learn quickly together than to initially agree on a detailled (but rapidly obsolete) definition of the future product. In this perspective, the agreement between two firms must be consistent in terms of joint work procedures and the means for dealing with unexpected problems or revised objectives.

The comparison of TR and CD project is typical of such a transition. In TR project, the machine tools suppliers did not participate in the design phase. Consensus was reached on a basis of theoretical initial technical specifications that had not been validated by those (the suppliers) who were supposed to implement them. In CD project on the contrary, the machine tool suppliers were involved in the colocated project through residential engineers from the beginning of the design. Common methodologies were negociated to identify problems quickly, to jointly formulate possible solutions, evaluate their economic impact, implement them, and finally optimize the elimination of decision-making inertia when effecting the required modifications. Those methodologies implied development of mock up, problem solving data base, sharing of the CAD specifications… During the course of the project, the proposals made by the various players in the design process were open for discussion and revision. Typically, suppliers were supposed to alert and ask for design changes when they anticipated feasability problems. They were supposed to adopt such a proactive alerting role, as opposed to a passive reaction to customer inspections.

- The supplier's commitment to an overall result, measured in terms of quality, cost, and time.

In co-development, the supplier's commitment covers the total design / testing / production / delivery process. The customer must be certain that the supplier will use its significant margin of manoeuvre to carry out the co-development project in the direction initially planned.

Due to this principle, the initial contract in project CD fixes globally the remuneration with special clauses dealing with modifications, as described in the following §. The shift to co-development transforms negotiated pricing into effective remuneration for suppliers; whereas budget overruns were usual under the traditional system.

- The integration of economic and technical imperatives : the contracting rules about modifications

In traditional projects the economic relation is ruled between purchasing and commercial agents who are largely cut off from the engineering arena of manufacturer and supplier. The dissociation is also temporal : first there are the technical decisions within the auto-maker, then the bidding and the economic negotiation, then the technical achievement, and lastly, the negotiation about the modifications. Under co-development, economic negotiation becomes a process of building value through the design process (during which technical variants are costed, the effects of modifications evaluated, etc.). Suppliers' remuneration is the result of specific achievement benchmarks, rather than solely made on the basis of accounting considerations formulated by the customer's purchasing department.

The contracting rules about design modification experimented on the CD project is typical in that perspective. Modifications are a classical problem in the auto industry. They can vary in importance: from the shift of an opening on a component, to a change in the overall style of the product. Budget overruns caused by modifications could previously reach 20% to 30% in the studied firm on a given project. For the auto-maker, a major advantage of the shift to co-development is that modifications tend to be reduced in number. Modifications carried out during Phase 2 are the most costly. To embark on Phase 2 is to embark on the stage of project irreversibility, or project reversibility only at an extremely high cost. Tardy discovery of the need for modifications involves heavy additional costs, since at this stage, the modifications must be made on the finished tools rather than on the preliminary designs. In other words, modifications can be very valuable during Phase 1, but are extremely costly during Phase 2.

Under the sub-contracting system, each modification becomes the subject of an amendment to the initial contract. Suppliers are free to negotiate a low initial price, since they know they will have an opportunity to “hike it up” during the life of the project. In order to persuade suppliers to play the game of early modification identification, the co-development contract includes (importantly) a clause specifying that no additional costs will be paid for late identification of the need for modifications. A comparison between the traditional and the co-development systems is quite illuminating in this regard.

Figure 3: Payment of modification costs in sub-contracting system

	Phase 1 (low cost for anticipated modification)	Phase 2 (high cost for unanticipated modification)
Coming from Customer	Customer	Customer
Coming from Supplier		Customer

Under the sub-contracting system, Auto-Maker X is wholly responsible for modifications. In Phase 1, since suppliers do not participate in the design phase of the project under this system, modifications cannot originate with suppliers. During Phase 2, if the tool-makers suggest modifications, Auto-Maker X must pay the costs, since he bears sole responsibility for the design.

Figure 4: Payment of modification costs in co-development system

	Phase 1 (low cost for anticipated modifications)	Phase 2 (high cost for unanticipated modifications)
Coming from Customer	Supplier (1)	Customer (3)
Coming from Supplier	Supplier (2)	Supplier (4)

(1) During Phase 1, the cost of modifications originating with the customer is defrayed by the tool-maker without any change in the contract. Suppliers are thus encouraged to seek compensation for cost overruns generated by the maker (e.g.: style changes, modifications in the safety system, etc.). This compensation, which reflects an improvement in tool design, leads to a reduction in tool costs (e.g.: reduction in the number of tools per vehicle-model from five to three). This clause motivates suppliers to provide any expertise not possessed by the auto-maker at the earliest possible opportunity. The converse of this argument runs as follows: if the auto-maker were to pay for all the modifications originating with it, tool-makers would not be motivated to compensate for them and would thus become less involved in the planning stages.[6] This incentive system has already been observed at firm J by Aoki (1994), who maintains that the more auto-makers protect sub-contractors from risk, i.e. the more responsibility auto-makers assume

[6] Suppliers can, however, contest the pertinence of a modification required by Auto-Maker X by referring it to a panel of peer assessors that meets at the conclusion of the project.

for cost overruns resulting from modifications, the less incentive suppliers will have to pursue innovation on their own.

(2) When suppliers pay the costs for Phase 1 modifications, they are encouraged to propose only those improvements that will result in lower tool costs. This is because, when suppliers lower the cost for tools during Phase 1, they improve their own profit margin, since they are contractually guaranteed payment at the price fixed during initial negotiation. Improvements originating with suppliers “go straight into the suppliers’ own pockets”.

(3) Auto-makers have an incentive to identify themselves needed modifications during Phase 1, since they will have to pay unanticipated modifications during Phase 2 themselves. This is the only exception to the fixed-price nature of the contract.

(4) When assuming total responsibility for tool design under co-development systems, suppliers pay the costs for all modifications originating with them. The high cost of Phase 2 modifications, acts as an incentive for identifying the need for modifications during Phase 1.

To sum up: since all Phase 2 modifications represent increased costs for the party identifying the need for them, this acts as an incentive for early identification. During Phase 1, suppliers are motivated to reduce the costs of the tools for which they are responsible by improving their design.

2. EVALUATION OF CO-DEVELOPMENT COST PERFORMANCE

2.1. Methodology.

Our study is comparative, evaluating the respective results of two projects: one carried out according to the traditional sub-contracting approach (TR project), and the other according to the conditioning factors described above (CD project). Our approach is differential: we have measured the performance differentials between

TR and CD projects. Hypothetically, the profit/loss differential observed between the two projects can be attributed to the shift (in one case) to the co-development method. Both projects studied were very similar in terms of vehicle-model, year of launching (less than two years of difference); also economic assessments were made in constant French francs (base: year of TR project). Furthermore, the basis of comparison for aggregating data was the same.

Our comparison is based on the analysis of three cost indicators: the estimated cost, the negotiated price and the value of modifications.

- In order to evaluate Phase 1 performance, *we measured, for all tools on Projects TR and CD, the differential between tool cost at the beginning of Phase 1 (or estimated cost) and cost of the same tools at the conclusion of Phase 1*. The first cost corresponds to the initial technical evaluation of the tools. We call this "estimated cost," and it serves as the basis for all of our measurements. Initial specifications for the tools are provided by the systems-engineers of Auto-Maker X: the customer knows how to specify the type of tools it wants to receive from the supplier. The same method of calculation—a widely recognized one, employed by suppliers—was used to determine the two costs on both projects. Calculations that do not appear were made for research purposes by the methods department at Auto-Maker X.

- In order to evaluate the impact of co-development on the auto-maker-supplier negociation, *we have measured the differentials between estimated tool costs and costs negotiated with suppliers for TR and CD Projects.*

- *Finally, we have measured the value of Phase 2 modifications as a percentage of estimated tool costs for TR and CD projects.*

The above indicators could be documented with the auto-makers data. The access to suppliers data was more difficult. These suppliers were competing with each other and were conducting negotiations with Auto-Maker X at the time of the research. The problems were solved due to both the credibility previously established by the field researcher (Garel, 1994), and to lengthy discussions undertaken with each supplier. A questionnaire and survey agreement enabled each supplier to understand our study objectives, and to prepare for each of our visits. Our investigation sought to evaluate the effects of co-development on the strategy, organization, and resources (human, design, plant, etc.) of these firms; and on the customer/supplier relationship from the viewpoint of the suppliers (commercial negotiation, contract signing, work at the planning stage, etc.). Two studies devoted to modifications for TR and CD projects and to the economic performances of these firms were also conducted.

2.2. Results of the co-development performance measurement

- *A reduction in tool costs.* Co-development generated a 7% reduction in tool costs at the end of Phase 1, whereas the traditional sub-contracting system posted a cost overrun of 11%. A tool-by-tool study shows that the reduction for the CD project reflects improvement in tool design during Phase 1, i.e. during participation of suppliers at the planning stage. For example, Supplier A succeeded in improving the process for one lot of tools under the CD project by reducing the number of tools from 12 to 4, representing a cost reduction of 48%. By contrast, the TR project registered an increase in the complexity of the tooling process during Phase 1 due to problems with delivering pertinent expertise in a logical sequence during the planning stage, to the lack of an improvement-incentive clause, and to the absence of the suppliers' own experts. We concluded that, under co-development, the Auto-Maker achieves savings equal to the cost overruns on the TR project (11%), and that suppliers will increase their profit margins if they can reduce tool costs (7%).

- *An increase in the negotiated price.* For the two partners, what effect does co-development have on the negotiated tool price? It is clear that under co-development the auto-maker pays more for tools during the initial negotiation, since the suppliers must anticipate modifications and profit margins during a single negotiation, with no hope of renegotiation. In fact, under the CD project, negotiated tool prices averaged at 23% higher than initial costing or cost estimates. Under the TR project, the differential was 16% (discrepancy = 7%, which is a benefit for the suppliers and a loss for the auto-maker). For suppliers, this differential measures the cost of future risks. Auto-Maker X did not, however, "push" the negotiation too hard for this initial co-development experiment under the CD project.

- ***A sharply reduced investment in modifications.*** The number of Phase 2 modifications was significantly reduced. They accounted for 49% of estimated tool cost under the TR project, compared to only 15% under the CD project (delta = 34%). In other words, investment in modifications under co-development were divided by almost 3.5, the result of a major reduction in modification volume. This observation is unique in the history of the automotive industry. The 34% reduction of modifications cost is clearly a profit for the auto-maker. We agree with the suppliers in considering that the reduction in modifications constituted a net loss in revenues, compensated by advantages obtained in production management (plant-flow equalization during Phase 2 was much easier, and production-times were shortened), and by the possibility of doing other business (income-generating business) during the time-period freed by modification reduction. Therefore, as a working figure, we have entered 0.

The figure 5 presents these results as a profit-loss balance sheet for auto-maker and suppliers.

Figure 5: Overall Co-Development Balance Sheet

Auto-Maker		Suppliers		
PROFITS	LOSSES	PROFITS	LOSSES	
Co-engineering performance: **11%**	Non-renegotiation of contract: **7%**	Co-engineering performance: **7%** Non-renegotiation of contract : **7%**		Phase 1
Reduction in modifications: **34%**			Reduction in modifications: **0%**	Phase 2
Total : + 38%		**Total : + 14%**		

Co-development appears here clearly as a win-win game. However, the aggregate-result effect conceals a genuine disparity. Only a supplier-by-supplier profit/loss breakdown (still in terms of the TR/CD differential) can provide the clear demonstration making further analysis possible (Figure 6).

Figure 6: Co-development profit/loss matrix

		Auto-Maker X	Suppliers
Supplier A	Pha 1 Co-Engineering Performance	PROFIT: 18%	PROFIT: 19%
	Non-renegotiation of contract	LOSS: 16%	PROFIT: 16%
	Phase 2 Modification reduction	PROFIT: 23%	-
	TOTAL	**PROFIT: 25%**	**PROFIT: 35%**
Supplier B	Pha 1 Co-Engineering Performance	PROFIT: 10%	PROFIT: 0.1%
	Non-renegotiation of contract	PROFIT: 1%	LOSS : 1%
	Phase 2 Modification reduction	PROFIT: 25%	-
	TOTAL	**PROFIT: 36%**	**LOSS: 0.9%**
Supplier C	Pha 1 Co-Engineering Performance	PROFIT: 0%	PROFIT: 4%
	Non-renegotiation of contract	LOSS: 6%	PROFIT: 6%
	Phase 2 Modification reduction	PROFIT: 68%	-
	TOTAL	**PROFIT: 62%**	**PROFIT: 10%**
Supplier D	Pha 1 Co-Engineering Performance	PROFIT: 7%	LOSS: 12%
	Non-renegotiation of contract	LOSS: 21%	PROFIT: 21%
	Phase 2 Modification reduction	PROFIT: 17%	-
	TOTAL	**PROFIT: 3%**	**PROFIT : 9%**

There is a clear differential in these results: between profits and losses, between profit levels, between customer and suppliers, and among the various suppliers. How can these be explained?

3. EARNING PROFITS FROM THE CO-DEVELOPMENT SITUATION

Co-development is advantageous to those suppliers capable of developing their design expertise on a long term.

3.1. Supplier expertise

Tool-maker profitability is heavily dependent on engineering expertise. We have noted and verified a strong positive correlation between supplier performance and supplier design-capacity as measured in a given supplier's (1) human resources (Kay 1993; Grant 1991); (2) technological resources; and (3) organizational resources.

Figure 7: Selected data on supplier engineering-resources

Suppliers	Engineering staff (studies, programming and simulation)	Design staff as a % of firm's total work force	Total number of individuals qualified to participate in planning	Existence of a project structure	Digital Studies	Rate of study sub-contract-ing	Number of CAD / CAM work-stations
A[7]	base 100	base 100	base 100	yes	yes	average	base 100
B	33%	84%	20%	yes	yes	low	50%
C	50%	123%	50%	yes	yes	average	75%
D	20%	130%	30%	no	no	high	25%

The Supplier B and D age-pyramids are relatively older than those of Suppliers A and C, a difference explained by the fact that design-department employees tend to be younger than those in other departments. It also reflects the considerable investment made by Suppliers A and C in a youthful and highly-qualified work force.[8] These young recruits also reflect heavy technological investment in digitalization and simulation—investments[9] enabling these suppliers to reduce design time and improve the management of unforeseen Phase 1 modifications.

[7]N.B. for reasons of confidentiality, we decided to express the data relative to Suppliers B, C, and D in a percentage of the base 100 corresponding to Supplier A, and to mask data on sub-contracting rates for design studies (average rate = approximately 50%).

[8] It is nevertheless the most highly-qualified suppliers, and often those of longest-standing, who participated in the auto-maker's Phase 1 planning stage. It should also be noted that metal-stamping as a field has historically had a long tradition of apprenticeship.

[9] For example, apart from training costs, a fully-equipped 3-D CAD workstation costs approximately FF 300,000.

Tool-Maker D has not developed a design department or planning facilities and, in the absence of a project team, this firm—small in size and European in scope—cannot offer co-development expertise to its customers. Its design department has not been significantly modernized. Studies are not digital, and investments in CAD are low. Despite a large design staff in terms of percentage of total work force, Supplier D sub-contracts much of its design-study work. However, this sub-contracting is poorly handled and creates a dependency situation for the tool-maker in relation to his own design-study suppliers.[10] The lack of project structure has created coordination problems between customer and supplier. Supplier D is the only one which did not reap any advantages from participation in Phase 1, and modification reduction was negligible. In contrast to the operations carried out with Suppliers A, B, and C, the auto-maker's engineers were forced to make trips during Phase 2 to the premises of tool-maker D more often under the CD project than under the TR project, in order to compensate for this lack of skills (Figure 8). Co-development revealed the structural weaknesses of this supplier.

Figure 8: Number of monthly visits to suppliers by Auto-Maker X representative during Phase 2

Suppliers	Non Co-Development	Co-Development
A	1	1
B	4	1
C	2	0.5
D	0.5	2

[10] The field covered by these design consultancies is industrial design in general and not machine-tools in particular. This non-specificity is reflected in the tardy identification of problems, since Supplier D does not possess the means for verifying all sub-contracted design work. Here we see that in order to sub-contract effectively, knowledge of how the job should be done must already be possessed internally. Tardy identification of errors creates tensions in the relationships between the design consultancy and the tool-maker's plant and are costly in terms of wasted time.

Tool-Maker B developed its design resources extensively for the planning stage, and also implemented a dedicated project structure. The design-department work force increased by 150% over four years. This firm concluded partnership contracts with outside design/planning consultants in order to strengthen its internal design resources. And, in order to help its partners adapt to the specifics of tool-making, the firm ultimately provided computer work-stations, software, and training programs for design-consultancy employees. Here, the dependency that holds Supplier D back has been addressed and remedied. (b) Over the past two years, Supplier B has gradually implemented a project structure cloned from that of Auto-Maker X. Internally, this project structure strengthens the relationship between the engineering and other departments. However, the performance of Tool-Maker B (overall loss of 0.9%) in the TR/CD comparison does not take into account the reorganization carried out following the CD project. The shift to co-development served as a strong incentive for this supplier to transform its structure and resources.

Tool-Maker A is positioned as a complete service-provider from the design of auto-body components to their final assembly. This supplier earned a substantial profit from co-development in the pre-production planning stage (profit of 35%). The firm developed its digital design and R&D departments extensively, and five years ago implemented a “heavyweight” project structure (Clark and Wheelwright, 1992). Within the firm, organization according to project is a factor which promotes consistency. The project structure “holds together” all the investments and reorganizations by linking them to one another within a coherent system. It is also an attempt to duplicate the auto-maker’s own organization, thus facilitating the customer/supplier interface. Supplier C, like Supplier A, has been developing its engineering skills for many years.

The ability to earn profits from a co-development situation is thus strongly dependent on skills provided by the supplier. A skill-based approach puts the interpretation of performance in terms of incentives and design processes into perspective. Front-loading design processes and project collocalisation, even when associated with economic incentives are not in themselves sufficient to mobilize suppliers at the inception of a project. Although they positively affect both the early identification of required modifications and tool-cost reduction, profits are largely generated by tool-makers' skills, and not merely by these economic incentives. Shifting economic responsibility onto the shoulders of the tool-maker is not enough; the means through which the tool-maker can assume this responsibility must also be provided by developing new engineering capacities, through human and technical investment within the supplier on one hand, and through participation of successive projects with the auto-maker on the other hand.

3.2. The long-term stability of the co-development relationship

Skills acquisition and investment by suppliers implies the extension of the inter-corporate relationship beyond a single project. Duration over time builds trust and develops learning. It also represents a guarantee of revenues, i.e. profit expectations are increased if the contract is renewed without subterfuge on either side. Suppliers will not undermine the interests of a customer that can guarantee steady revenues. Under the system of joint participation described by Imaï and Itami (1984), the two parties agree to renew their cooperative venture if each one has fulfilled its obligations. Game theory demonstrates that the duration of the relationship constitutes an incentive to cooperate. In a survey dealing with the American and Japanese car industries, Cusumano and Takeishi (1991) note that the relationship between contractors and auto-makers lasts for over ten years.

Further, Donada and Kesseler (1997) note that customer and supplier involvment in co-development relationships today lasts for an average of 23 years. Co-development is conceived as a game that is continuously replayed, but its total lifespan is determined by results. Although co-development reflects a strategic change for Auto-Maker X, and although it involves a longer-lasting relationship than the traditional one for design sub-contracting, the customer still does not guarantee the supplier that it will be systematically selected for each new development. Behind this uncertainty, suppliers perceive a contradiction between, on one side, a coherent and motivating proposition from the Auto-Maker X management on partnerships with suppliers; and, on the other, organized debate within the firm on the desirability of an alternate method ("what if, ultimately, selection of the lowest bidder turned out to be the least costly solution?"). This vacillation worries suppliers. Co-development—and the commitment to long-term organization and investment it involves—requires a degree of stability in the organizational choices made by each of the partners. "Our investment strategies are strongly dependent on the continuation of a sustained volume of stable operations in the future" (all suppliers). In today's context of drastic reduction in design costs by auto-makers, the pressure on suppliers at the time of negotiation is very strong. The cost factor, as a determinant in the selection of suppliers, is indeed an integral part of the inter-corporate cooperation system. The estimated/negotiated cost differential observed between TR and CD projects (+7%) is sharply reduced for projects after the initial CD project. This pressure on prices reduces revenues, affects supplier profit margins adversely, and over time raises the question of how long co-development can be sustained: "like other auto-makers, X requests a 20% reduction for each new project; the problem with a 20% reduction is how to maintain profit margins" (all suppliers).

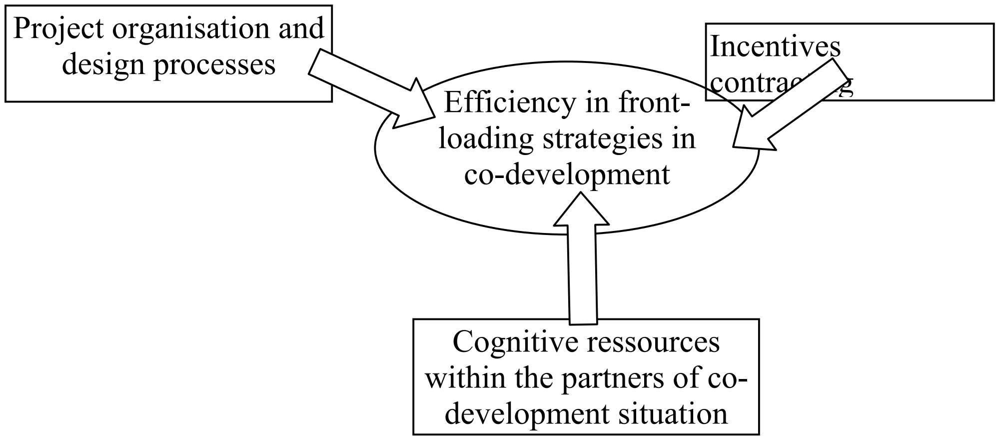
Duration does not depend solely on the amount of time allowed by the customer for the co-development relationship. It is also a function of the co-development strategy of management and suppliers. What is the “strategic intention” (Hamel and Prahalad, 1989) of these managers in terms of co-development? “Strategy” is understood in this context as the fit an organization achieves between its own resources/skills and the opportunities/risks created by its external environment (Hofer and Schendel, 1978). The formulation of medium-term strategy is the only way to give coherence to the investment and organizational choices implemented by suppliers in the context of co-development. The tool-makers’ strategies are closely linked to the proportion of their revenues accounted for by Auto-Maker X. As it happens, Auto-Maker X is a major customer for the suppliers we studied. The only supplier-managers who failed to offer a strategic vision were those of Supplier D. They consider that the implementation of co-development is “unnatural” since firms are not intended to cooperate, but to organize their relationship via the market. This supplier’s lack of project structure and investment in design skills reflects its lack of strategic perspective. By contrast, the investment of tens of millions of French francs in an ultra-modern plant, the development of engineering skills, the implementation of data systems, and the modernization of organizational systems at Supplier C reflect a strong strategic vision.

Conclusion

How to implement front-loading problem-solving strategies through co-development ? This article explored this question on the case of a relation between a auto-maker and its die-tools suppliers, a typical situation where product and process design are tightly associated in making the development performance.

Our analysis showed that to be efficient in that perspective, the relations have to meet three kinds of conditions. On the organizational level, co-design and front-loading methodologies ; on the contractual level, incentives for upfront learning and problem solving ; on the cognitive level, engineering capacities and multi-projects cooperation learning. With this complex of conditions, co-development appears as a win-win situation, which is generally not the case if one of these conditions fails.

Figure 9: the determinant factors on codevelopment front-loading efficiency.



Our study, closely focussed on machine tools for the automotive industry, leaves some consequences of co-development unexamined. For example, we have not studied the effects of this new organizational method on development time-frames, a major factor in the competition between firms developing new products. The development time-frame was shortened by over 10% between TR and CD projects, a tendency that accelerates with subsequent projects. Also unexamined are the effects of co-development on human-resource management (e.g.: stress and sometimes professional burn-out at the end of certain co-development projects; the effect on the relationship between project teams of coexisting but differing modes of customer relations practiced within the same firm). Nor have we further examined the effects of co-development on the machine-tool suppliers market. Today we are witnessing a definite trend towards vertical integration (e.g.: Comau in Italy) reflecting demands for industrial competence from design through production; and towards a widening gap between the top-ranking suppliers (co-developers) and those below them. Inter-corporate cooperative efforts are redefining the frontiers of the firm itself, and are diversifying the nature of inter-organizational relationships.

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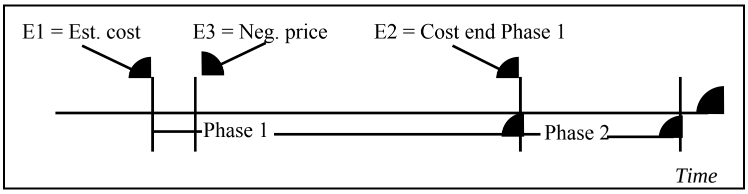
APPENDIX

Below we present the calculation method, formulated *ad hoc* for our research purposes, used to arrive at the various differentials enabling us to measure co-development performance. With E1 = estimated cost, E2 = cost at end of Phase 1, E3 = negotiated price, E4 = cost of Phase 2 modifications.



suppliers	tool reference	cost	cost and price	results
A,B,…	detail by tool in lot	E1......... and E1......... and E4.........	.........E2.......... ....E3..........	diff. E1and E2 in % diff. E1 and E3 in % E4 in % of E1
	total lot	∑E1......... and ∑E1......... and ∑E4.........	.........∑E2....... ....∑E3.......	diff. ∑E1 and ∑E2 in % diff. ∑E1 and ∑E3 in % ∑E4 in % of E1
total suppliers		∑(∑E1)..... and ∑(∑E1)..... and ∑(∑E4).....	.....∑(∑E2)....... .....∑(∑E3).......	diff. ∑(∑E2) and ∑(∑E1) = performance in Phase 1 diff. ∑(∑E1) and ∑(∑E3) = effect of non-renegotiation of contract ∑(∑E4) in % of E1 = modification reduction

The above table was drawn up for both the CD and TR projects. The data on tables 3 and 4 in the body of the article show the differentials between the results obtained for each one of the projects (double-framed box in the above table).