Early supplier involvement: a review and proposal for new directions in research

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Abstract: Systematic supplier participation in the product development process began in Japan in the 1960s. By the late 1980s, with the "Japanese miracle", this practice was considered one of the main sources of competitive advantage of Eastern companies. This study demonstrates the need for new directions in research on this theme, focusing on the form of its application, its increasing scope, the use of alternative sources of data and greater integration among the different research methods. A bibliographic review is also presented, analyzing the advantages and disadvantages identified to date and the evolution of the literature on the subject.
Keywords: buyer–supplier relationship, product development, earlier supplier involvement, and collaboration

1. Introduction

Much attention has been accorded to the process of product development in the industry. In a highly competitive environment marked by the internationalization of operations and fast technological change, the superior performance of this process has become an essential condition to ensure technologically up-to-date product lines whose characteristics of performance, cost and distribution meet consumer expectations.

Among the several relevant aspects of this process, a practice that has evoked much interest and become increasingly applied by companies is the systematic involvement of suppliers in the product development process of their customers. This article employs the term Early Supplier Involvement (ESI), since it is the term most widely used in the early articles published in this area of research.

During the analysis of the literature on ESI it was found that, notwithstanding the abundance of studies developed on this relatively recent subject, few implications had been derived for the adoption of this practice.

The purpose of this article is to recommend directions to be taken in ESI-related research so that knowledge can be acquired to aid professionals and companies in the adoption of this practice. It is demonstrated that new paths should be trodden in regard to the focus, scope, sources of information and integration, generating knowledge and information about the practice of ESI for business professionals and specialists in the area to refer to during practical interventions.

A bibliographic review on the subject was used to develop this study, which began with an analysis of the basic articles that aided in the identification of a list of important journals. An analysis was then made of those main periodicals, starting from 1985, in which the principal articles on the theme were identified. This identification work was complemented with key word-based searches in *Current Contents* (published by the *Institute of Science Information- ISI*) on the Internet.

Item 2 consists of a brief history of the emergence of the ESI practice and the principal articles published on the subject. Item 3, a synthesis, identifies the volume of research work published and included herein as the principal body, as well as the main lines of research. Item 4 consists of a summary of the main theoretical models applied in the area which, together with the remaining items, supports the analysis of the literature and future research needs. To conclude, item 5 presents the final remarks.

2. ESI literature review

2.1. Historical overview

Increasing and systematic supplier participation in product development originated in Japan following World War II. According to NISHIGUCHI (1994), with the sudden growth of demand and competition in the Japanese industry from the mid-40s to the late 60s that resulted, among other factors, from the Korean war, closer buyer-supplier relationships.. Thus, a pyramidal hierarchic system was formed in which the buyer interacted with a small number of suppliers who, in turn, became interlinked with other sub-suppliers. In this institutional arrangement, the companies comprising the different links in the productive chain consolidated a relationship that was recognized as being based on mutual trust and development. The buyers thus delegated several tasks to their suppliers, using them systematically as the main form of responding to the significantly increased demand. This approach led to actions to systematically involve suppliers in the product development process. First level suppliers participated in the entire development process of their customers, presenting suggestions for the final product and taking responsibility for the detailing, tooling and prototyping of the parts or subsystems they would produce and deliver.

To say that this practice originated in the Japanese industry does not mean that Western industry had no cases of suppliers participating in the product development process, either during or prior to this period. Rather, it means that the few cases where this kind of involvement did exist were the exception to the general rule, according to which suppliers were given totally developed designs including, in many cases, the tooling needed to produce the product (WOMACK et al, 1992).

While the practice of Early Supplier Involvement was developed in the 50s and 60s in Japan, research about the subject only began in the 80s. This was the period of the "Japanese miracle" and much of the research effort focusing on management and economy sought to define and understand the factors and practices that made Japanese companies more efficient and competitive. Researchers of several areas identified the relationship of Japanese buyers with their suppliers, including participation in product development, as one of the main factors that justified the greater efficiency of Japanese companies.

The first research work that brought to light the importance of supplier involvement in the process of product development was that of IMAI, NONAKA and TAKEUCHI (1985). This was soon followed by CLARK (1989) who, based on a large amount of collected data, also presented important work reinforcing the importance of the theme, which was part of the research work later published by CLARK & FUJIMOTO (1991). In 1995, BROWN and EISENHARDT (1995), in a review of the literature on product development, highlighted the importance of the subject, considering the relationship between buyers and their suppliers among the most important areas for the study of product development. The mid-1990s marked the beginning of the publication of a large number of articles, of which the principal ones are analyzed in this study.

2.2. Research criteria

Each of the articles was analyzed in regard to its objectives, the methodology employed and its main results. With regard to the principal results, the benefits, barriers, general conclusions and theoretical models developed were identified.

The analysis of benefits evaluated the articles' findings concerning the effect, i.e., the contribution of ESI to the performance of the product development process. In terms of barriers (recommendations), a compilation was made of the factors that hindered these positive results or that brought negative results to the product development process. An analysis was also made to determine whether or not the reports offered models and, in positive cases, the type of model and the variables employed. The general remarks consisted of analyzing the other conclusions presented by the reports.

2.3. Main articles

The main articles are listed in a systematized and succinct manner in table 1. This table shows the principal production on the theme, in chronological order, and contains a summary of the analysis of each paper according to the criteria presented earlier herein.

3. Synthesis

3.1. Key figures

A total of 24 main papers were analyzed, 10 of which were surveys compiling data from approximately 843 suppliers, 162 automakers (responsible for development), 291 member companies of the Project Management Institute, 79

small and medium sized companies and 58 projects. Another 8 are case studies in which 31 companies were analyzed and their suppliers. The remaining 6 articles are theoretical. Although the first papers were published in the early 90s, only in the mid-90s was a significant effort made; indeed, 19 of these papers, or 79% of the total number identified as principal articles, were published from 1995 onward. The peak occurred in 1997, when most of them, 9 in all, were published. Thus, the last few years have been marked by a very significant increase in research on the subject.

Despite the large number of analyzed practical experiences presented in these articles on the subject, considering how recent the practice is, very few practical results have so far been generated. Indeed, of the articles listed herein, only 8 propose theoretical models have to be analyzed in depth. From those models, 4 are typologies (of parts or types of suppliers) related to different degrees of responsibility and 4 are models based on specific subjects such as information flow, application of value analysis, among others. It should also be noted that the first articles have focused on the effects or benefits of the ESI practice, while the more recent papers have increasingly focused on the identification of important factors or characteristics and on the development of theoretical models that aid the application of ESI.

4. Overview of the proposed models

One of the first theoretical models is the one presented earlier by CLARK (1989) and CLARK and FUJIMOTO (1991), which places buyer-supplier collaboration in product development as a company strategy that is principally and intimately related to the inter-project strategy, evidencing a viewpoint that is more mother-company oriented and attributing a more passive role to the supplier. To characterize this type of relationship, CLARK and FUJIMOTO (1991) present an interesting typology of parts, dividing them into Supplier Proprietary Parts, Black Box Parts and Detail-Controlled Parts (Functional parts and Body Parts). Within this typology, they characterize the scope of the buyer's project (how much is done by buyers and how much by suppliers) and relates it with the performance parameters of the product development process (product quality, lead-time and productivity). This typology served as the inspiration for a significant portion of the articles presented on the subject.

In HELPER's (1991b) work, in which the author analyzes the incentives for supplier participation in the product development process in the American automotive industry, participation is seen as the result of bargaining between buyer and supplier, in which the supplier will invest in product development capacity if it maximizes the profits generated by the level of commitment with the buyer. Suppliers and buyers would, thus, have to overcome two obstacles to promote participation: first, organize the transfer of information so that joint benefits were found and second, organize themselves so that these benefits would be used to the advantage of both sides. This author's model assumes the following bargaining process: 1) the buyer bargains with the supplier for a relationship with a high level of commitment, and 2) the supplier accepts or rejects the hypothesis.

KAMATH and LIKER (1994) show a model of types of relations between suppliers and buyers in the product development process that is based on an extensive study of the world class Japanese automakers, as shown in table 2. The table summarizes the types of roles according to the responsibility assumed by the supplier in the development process.

The authors, therefore, suggest that the buyer could take advantage of the supply chain to improve the performance of the product development process by adopting the following actions: 1) determine the type of relationship with each supplier, the levels of component complexity and the supplier's capacity; 2) try to fit them into the model in order to have access to their technological capacities; 3) monitor this capacity and manage the transition from one model to the other; and 4) maintain a stable development process and clear guidelines for its key suppliers.

The suppliers listed in the table should seek technological and management capacitation of the development process, in line with their responsibilities in the model of relationships summarized by the table. Thus, the suppliers should seek to: 1) identify the complexity of their products and their capacitation, seeking to fit into this model; 2) attempt to carry out transactions from one relationship model to another with increased interaction with their buyers, increasing their capacitation and the technological content of their products (cautiously, since this requires large investments); 3) understand and internalize their customers' product development process; 4) try to understand their customers' strategic needs; and 5) always seek to develop their technological capacity, since it is an important factor in their relationship with the buyer.

ROY and POTTER (1996) propose a theoretical model that characterizes different types of development within a supply chain. This model is divided into two main groups: *Buyer-Driven* and *Supplier-Driven*. The first group consists of three types: *In-house* (the traditional type entirely developed by the buyer); *Competitive Tendering* (in which the buyers provide the design specifications for open competition among many suppliers); and *Partnership Sourcing* (buyers pre-select the suppliers that will collaborate in the product development process). The second group, managed by the supplier, comprises the *Supplier Interactive* type (the supplier develops the design in a continuous interaction with the buyer); and *Fully Devolved* (the supplier ascertains requisites, develops, delivers and installs the item completely, as in the case of large pieces of equipment). In this article, the authors also identify several factors that condition the choice among these models of involvement, such as: type of industry, company and product, location of the company in the chain and level of innovation of the development project.

TWIGG (1998) presents a classification to characterize supplier involvement, which is an improvement of the parts classification developed by CLARK (1991). This same author also presents a model to classify the type of guest engineer and his role, which is fundamental to buyer-supplier integration in the product development process (TWIGG, 1997).

LIKER et al. (1996) developed an interesting model whose criterion is the manner in which the design information is exchanged between the buyer's and supplier's design teams, which these authors call *Point* and *Set-Based Design*. In the most traditional type of development, *Point-Based*, a cycle is followed in which many alternatives are generated in each stage, the best one among them is selected and, once the best option has been defined, the result is passed on to the next stage, where another design group begins its work and can return alterations. In the case of *Set-Based Design*, instead of working with an optimal alternative, designers gradually reduce the set of possibilities along the development process, eliminating alternatives that are clearly inferior and passing on to the other phases a set of options that may be different alternatives of design and parameters (several optional designs and specifications). According to the researchers, in *Set-Based Design*, the supplier must be capable of dealing with a greater degree of ambiguity, which therefore makes it more confusing and difficult. On the other hand, this would produce more radical innovations (breakthroughs), superior designs, and improved final product integration.

VROOM (1996) presents a data model that seeks to establish the information requisites needed for supplier involvement in the initial stages of the development process. This is a theoretical model containing the dimensions of information, process and organization, which served as the basis for the construction of a prototype of a computational tool to support this practice.

DOWLATSHAHI (2000) compiled a theoretical model comprising the principal hypotheses and corollaries about ESI and verified the model in a case study. The propositions he compiled are: "*1) ESI is the most crucial aspect of sourcing; 2) ESI requires R&D investment by suppliers; 3) the relationships between buyers and suppliers must be based on confidence and trust; 4) purchasing should reduce the number of suppliers in every part category; 5) there must be a free flow and sharing of information between buyer and suppliers in the part and product design stage; 6) buyers should have formal and organized plant visitations to suppliers plants; 7) supplier selection, evaluation, and certification should be based on long-term strategic partnerships; 8) supplier training and meetings are the core of buyer-supplier relationships*". Hence, although these hypotheses, taken together, form a set of recommendations for integration that allows it to be assumed as a model, its high degree of abstraction renders it of little use in decision-making or in gaining a deeper understanding of ESI. In this study, the relationship between a buyer and his different suppliers was analyzed, but the author was unable even to customers into a deeper discussion about ESI.

5. Analysis of the existing articles and a proposition for new directions

One of the first facts that draws one's attention in the literature about ESI is the strong emphasis on the effect of supplier participation in the product development process, i.e., the focus on the assessment of its real benefit for a company's performance. Keeping in mind that the initial research work on the theme appeared in the context of the "discovery" of the Japanese paradigm in the late 1980s, it seems natural that the basic focus of the researchers' efforts was directed at evaluating these effects.

As for the effects of ESI identified in the literature, one's attention is initially drawn to the fact that all these articles converge in regard to the positive role of ESI in improving the

degree of product innovation. According to the authors, stimulating the involvement of suppliers in the product development process can transform them into a source of technical solutions and technological development for the buyer.

IMAI et al. (1985) came up with the first major evidence of the effects of supplier involvement in the development process, identifying only positive effects and strongly emphasizing this advantage in terms of technological innovation. On the other hand CLARK (1989), who participated in the research of CLARK & FUJIMOTO (1991), in addition to the virtues, stated that there is a "*trade-off*" between the effect of supplier involvement in product quality and productivity performance and engineering lead time. Therefore, in the words of these authors (CLARK & FUJIMOTO, 1991, p.160), "The challenge of managing the relationship with suppliers is to explore the benefits of lead time and engineering hours while minimizing the deterioration of product quality."

In time, new negative evidence confirmed not only lower product integrity and quality but also questioned the advantages in terms of cost and reduced development lead time that had been pointed out by the pioneers (LITTLER et al 1995; HARTLEY et al. 1997). At the same time, research work was published demonstrating the positive effects of supplier involvement in product development in regard to one or more parameters (KAMATH & LIKER, 1994, HARTLEY, ZIRGER & KAMATH 1997 and RAGATZ, HANDFIELD & SCANNELL, 1997).

Reports were also published indicating that the effects of this practice were strongly contingent on the context in which supplier involvement in the product development process occurred. LIKER et al. (1996) suggest that good ESI results depend on the form of integration adopted. LIKER et al. (1996) point out certain peculiarities of the organizational and technical mechanisms that support the relation between companies and influence the effects of ESI. The interpretation of HANDFIELD et al. (1999) is that many companies perceive the importance of ESI, but do not know how to implement it.

Thus, insofar as the effects of development lead time, delays in design, product productivity and quality are concerned, the results of past research work have been contradictory, some of them identifying positive effects and others finding negative ones in the performance parameters. This apparent contradiction, however, is due to the influence of the way that supplier involvement is carried out, i.e., how this involvement comes about because, firstly, the research papers that suggest positive and/or negative effects do not consider the question in detail (e.g., CLARK, 1989; CLARK & FUJIMOTO 1991; HANDFIELD & SCANNEL and HARTLEY et al., 1997; BIDAULT et al. 1998, p.731), and, secondly, because recent articles have revealed that this practice can generate both positive and negative results, depending on the characteristics of this integration (LIKER, SOBEK, WARD, CRISTIANO,1996; and LIKER et al. 1996). Moreover, many of the papers included in the first group present, as the fundamental direction for research in the area, an understanding of how this involvement and integration among companies occurs. CLARK (1989, p.1261), for instance, recognized that "*…the critical managerial problem in product development is not securing effective collaboration within the firm, but managing the supplier to achieve integration in engineering efforts*" and "*There is a need for more research on the nature of integration, particularly in the development process and its interaction with the nature of the financial and commercial relationships between firms*"; and more recently, BIDAULT, DESPRESS & BUTLER (1998, p.731) state, "*We would also recommend further research in qualitative tradition in order to understand more closely the way organizations and managers make choices with regard to ESI*"

From the analysis of the effects, therefore, it is evident that the practice should be considered as having either positive or negative effects, according to how it is applied. Consequently, the direction of future research in the area should focus on the mechanisms that support the buyer-supplier relationship and joint designing. Attempts should be made to identify the characteristics of the mechanisms that make supplier involvement a means to carry out development projects at lower costs, with higher quality and in less time. A good start for an in-depth examination of this issue is to analyze the theoretical models of the published papers, which are compiled under item 4.

A comparative analysis of these models indicates that most of them characterize supplier involvement in product development, generally speaking, by degree of responsibility, by phases of the development process in which there is involvement and

by scope (i.e., amount of work done by the supplier). The models consider these variables at a high level of abstraction, using very similar typologies of parts or types of supplier involvement. Many important aspects of this involvement such as quality of the information exchanged; types of information exchanged; tools, resources and devices employed; a history of contracts; legal aspects between purchasing and development sectors, among others are, therefore, not considered in detail. The most in-depth studies on the subject are limited to certain aspects such as information systems (VROOM, 1997) and the choice of supplier partner (HANDFIELD et al., 1999), disregarding many important questions involved in this process.

Thus, the theoretical models developed in the area of ESI can be considered highly abstract but not comprehensive. Little emphasis is given to the aspect of how to put ESI into practice and to the available resources and tools that can be used for this purpose. It is, therefore, necessary that future research work focus on the study and understanding of the mechanisms of participation and of managerial aspects that ensure positive results, to which end broader models must be defined.

As for the method, it was found that most of the articles consist of case studies which, even when dealing with specific aspects of the theme, nonetheless do not offer a deeper vision of how to undertake this participation. The remaining articles consist of surveys based on generic and broad hypotheses, mainly dealing with the effects of the practice. This situation limits the understanding of the mechanisms needed for successful ESI. "Statistical" proof of those hypotheses are useless if the paucity of knowledge about the occurrence of this practice fails to allow for these broader propositions to be linked to the practical questions that company professionals actually face when they need to employ it. In the absence of models or more solid concepts to back up the survey-based hypotheses, research in this area will continue to find it difficult to infer solid managerial implications.

Another important question is the source of information that has preferentially been used to establish some correlation, which, in most of the articles, consists of the opinion of specialists. Few companies keep structured records on the practice of ESI, so that the opinion, experience and memory of professionals and specialists who deal with the subject are, in fact, the richest and most meaningful source of data. However, one must keep in mind the innumerable limitations that the choice of this kind of source represents with regard to temporal aspects, comparisons between cases and, particularly, the level of detail achievable. For this reason, a lack of more precise descriptions is felt regarding the forms of operativity, with detailed information illustrated by documents. Hence, it would also seem that an important path to be trodden toward the development of this research area is the use of other research methods (such as participatory observation) and alternative sources of information (such as document surveys, etc.). These methods and sources may aid in the development of research work that delves deeper into the details of the practice, in line with the direction pointed out earlier.

Another major barrier is the lack of research that takes into account the various aspects of ESI. The scope of the published work is restricted, considering, as it does, only a small part of the dimensions of this problem. It is, therefore, necessary to develop work that takes into account not only the organizational dimensions (guest engineers, cultural integration etc.) but also the legal (contracts, timespan, etc.), financial, resource-related (tools methodologies, software, computer systems, etc.), and strategic (commitments, letters of intention, etc.) dimensions of shared knowledge and any other aspects that may be identified.

To summarize, the paths that should be followed in continuing research on ESI are:

Increased scope of research work: ESI should be analyzed considering the greatest possible number of dimensions and using an integrated approach. The different aspects must be analyzed jointly, i.e., organizational (structure of the teams, division of team responsibilities, mechanisms of integration between teams, among others), legal (what type of contract, at what time to sign the contract, etc.), personnel (guest engineers, interpersonal relations), as well as those related to knowledge, technology, resources, tools, among others;

Emphasis on the mechanisms and factors that lead to the efficient adoption of ESI: transfer the emphasis of research work to the identification of the factors, characteristics and forms of operativity that make the latter efficient and improve the product development process of both the buyer and the supplier (this vision is far less explored by the literature). This includes focusing on the construction of theoretical models that support the application of this practice;

Use of alternative sources: make uses of analyses based on multiple sources of data such as participatory observation, observation, analysis of documents, etc.

Multiplicity of Methods: data should be collected from different research methods in a more complementary manner, with survey-derived hypotheses based on in-depth case studies and vice-versa.

6. Final remarks

This study presented a bibliographic review of supplier participation in the product development process, detailing the origins of the practice, the bibliographical evolution of the subject, effects of ESI on the performance of the product development process and the theoretical models proposed by the authors of the area.

Several conclusions derived from this analysis. It was demonstrated that emphasis in research on this subject should focus on the factors and characteristics that lead to positive results in the adoption of ESI. Analyses and models should also be developed that take into account the different aspects related to the practice in an integrated manner. This research work should also, whenever possible, use alternative sources of information and methods rather than those that have preferentially been employed in the area, i.e., case studies and surveys.

Finally, it should be pointed out that this subject has received much attention in the area of product development and among company professionals. The professionals analyzed by HANDFIELD et al. (1999), for instance, stated that efforts would be made in their companies to intensify this practice and to bring their suppliers closer to their product development processes. The move toward concentration and strategies for the internationalization of development efforts seen today in the most varied industrial sectors is also a contributing factor and will certainly bring new challenges for the incorporation of suppliers in the process of product development.

The research work we are currently engaged in aims to develop a company model-based tool to support a more systematic and integrated analysis of the ESI practice. This tool is expected to be employed in the development of research on ESI, in line with the directions presented herein.

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Table 1 – summary of the main articles.

Author/Year	Objective	Methodology	Benefits	Recommendations and General Conclusions	Model
IMAI, K.I; NONAKA. I.; TAKEUCHI, H. 1985	Identify factors for the superior Japanese performance	Case Studies (5 innovative projects)	Increased flexibility and speed; High rate of innovation	Supplier involvement may explain the superior performance of Japanese companies.	
CLARK, K.B., 1989 & CLARK & FUJIMOTO (1991)	Determine the effect of the scope of the project on the performance of the PDP	Survey (58 projects / worldwide automotive industry)	Supplier involvement (scope of the project) reduces lead-time and increases productivity, but reduces product integrity (quality).		Buyer-supplier relationship model characterized by a type of part.
HELPER, 1991a	Analyze the incentives for ESI in the American automotive industry.			Suppliers and buyers would have to overcome two obstacles to promote participation: 1) organize the transfer of information in such a way as to find joint benefits, and 2) arrange for these benefits to be used by both parties.	Bargaining game between buyer and supplier.
KAMATH, R.R.; LIKER, J.K., 1994	Identify the best possible PDP techniques in order to manage the suppliers.	Case Studies (3 Japanese automakers/ 143 Japanese suppliers/ 189 American suppliers).	The hierarchical pyramidal structure of the Japanese suppliers led to the best performance.	There should be different types of suppliers according to the role they play in the PDP. Japanese suppliers appear to be better qualified to support their buyers in product development.	Types of relationship according to the responsibility assumed by the buyer.
TIDD, 1995	Analyze aspects of the intra and extraorganizational relationships of the development of complex products.	Case Studies (automation industry, including Japan, Europe, USA)		Inclusion of the supplier depends on the type of design innovation. In Japan, company networks set up to develop a product tend to be more open, which increases the degree of innovation.	
LITTLER, D.; LEVERICK, F.; BRUCE, M., 1995	Identify risks, benefits and key factors for collaboration in product development.	Survey (managers and professionals / communications industry)	The main advantage is the fast incorporation of a technology.	Leads to coordination and culture-related problems. A large proportion (40%) state that it increases development-related costs and lead times.	
LIKER, J.K.; KAMATH, R.R.; WASTI, S.N.; NAGAMACHI, M., 1996	Examine the difference between the USA and Japan in regards to supplier involvement in product design.	Survey (143 Japanese and 189 American autoparts manufacturers).		There are no major structural differences between the Japanese and the American automotive industry supply chains. The difference in performance should, therefore, be explained by the characteristics of the relationship.	

Author/Year	Objective	Methodology	Benefits	Recommendations and General Conclusions	Model
ROY, R.; POTTER, S., 1996	Study product development in complex industrial chains.	Methodology: 4 Case Studies (British Rail; Netherlands Railways; Rolls Royce and British Coal)		Incorporation of suppliers in the product development process would depend on the characteristics of the complex/industrial chain.	To characterize different types of development within a supply chain.
VROOM, 1996.	Develop an information system to aid ESI.	Theoretical			Model covering the aspects of information, process and organization.
LIKER, D.; SOBEK, D.K.; WARD, A C.; CRISTIANO, J., 1996	Make a comparison between the USA and Japan of two models of relationships with suppliers in the product development process (Set Based and Point-Based).	Survey (92 Japanese and 119 American autoparts manufacturers)		Depend on the approach. Demonstrates that the Set-Based approach (in which information exchanged between buyers and suppliers is greater, more diffused and based on several alternatives) leads to better design and greater innovation.	According to the way design-related information is exchanged between the buyer and supplier design teams.
DOWLATSHAHI, S., 1997	Identify a standard for the buyer - designer relationship within a simultaneous engineering environment.		Conceptual		Set of corollaries and principles for the buyer - designer relationship in a simultaneous engineering environment.
HARTLEY, J.L.; ZIRGER, B.J.; KAMATH, R.R., 1997	Analyze whether management of the buyer-supplier relationship reduces buyer and supplier-related delays.	Survey (professionals of 79 automakers).	Demonstrates that working with high capacity suppliers reduces the risks of design-related delays.	The mechanisms of this participation they consider, in this case, supplier involvement in the initial stages of the buyer" development process, increased responsibility for the design, and improved communication between buyer and supplier, were not confirmed as having a positive influence in reducing these delays.	
RAGATZ, HANDFIELD, R.B.; SCANNEL, T.V., 1997	Analyze the management practices and environmental factors that affect supplier participation in the product development process.	Survey (professionals from 83 companies in the state of Michigan, USA).	Lower cost of purchased material, quality and reduced lead time for product development, access to new technologies; possibility of influencing the direction of the supplier's technological development; identification of problems in the early stages of development.	Resistance on the part of different hierarchical levels in organizations; Self-sufficient culture common in the development sectors; Fear of revealing technological information. This is a strategic issue that may lead to improvement in the new product development process if the barriers and environmental factors are taken into account.	

Author/Year	Objective	Methodology	Benefits	Recommendations and General Conclusions	Model
LARSON, E. DREXLER, J.A, 1997	Identify the barriers against cooperation in product development projects.	Survey (professionals from 291 member companies of the Project Management Institute).		A compilation of several attitude and interpersonal barriers concerning the structure of the project, the partnership, the skills and knowledge and the lack of commitment.	
MAURER, 1997	Propose communication between buyer and supplier in the product development process.	Conceptual			Model for the buyer-supplier link based on the Value Analysis technique.
HARTLEY, J.L.; MEREDITH, J.P.; McCUTCHEON; KAMATH, R.R., 1997	Evaluates ESI in small and medium sized companies.	Survey (professionals of 79 small and medium sized companies).		Increases the complexity of the design. Adopting the techniques of supplier involvement in the product development process would not bring benefits, since it would lead to greater complexity of design.	Evaluates ESI in medium and small companies, supplier participation in the PDP: involvement time; design responsibility; frequency of communication.
TWIGG, D. 1997	Analyzes the role and responsibilities of guest engineers.	Case Studies (1 automaker and 6 autoparts manufacturers of the UK).		Suppliers should focus on buyers' development process. Both suppliers and automakers should seek the ideal relationship and use guest engineers in the initial phases of design. Identify the different roles of a guest engineer; Managers should identify and manage these different roles.	
CALABRESE, G., 1997	Examine human, technological and organizational resources that cooperate in R&D.	Case Study (a German automaker)		It is necessary to focus not only on the techniques but also, principally, on the process of learning, data transference, motivation and, above all, on the capacity to allow for the joint work of different skills.	
TWIGG, D. 1998	Analyze the relationship of the design activities at an automaker and at six key suppliers.	Case Studies (1 automaker and 6 suppliers).		Suppliers should focus on their buyers' development process. Both suppliers and automakers should seek the ideal relationship using guest engineers in the initial phases of design	Conceptual Model: Types of suppliers classified by responsibilities.
JASSAWALLA, A R.; SASHITTAL, H.C., 1998	Propose a conceptual model of collaboration in product development.	Case Study (exploratory and qualitative: 10 companies)			Conceptual model that considers several variables, their definitions and interrelations.

Author/Year	Objective	Methodology	Benefits	Recommendations and general conclusions	Model
BIDAULT, F.; DESPRESS, C.; BUTLER, C., 1998 a,b	Analyze the motives for the adoption of ESI.	Survey (designs of 25 automakers from 3 regions).	Greatest number of supplier initiatives.	Lower product integration. ESI is more a question of the internal and strategic issues of a company's than a need in face of external factors.	
KARLSSON; NELLORE; SÖDERQUIST, 1998	Discuss design specification-related problems with suppliers and analyze their causes.	Survey (300 suppliers of an automaker); Case Studies (one automaker and two suppliers).		Specifications should be developed and managed interactively throughout the process (changes are inevitable). Suppliers should assume a proactive role in these specifications. Supplier's participation should begin during the buyer's specification definition phase.	
HANDFIELD, RAGATZ, PETERSEN, MONCZKA, 1999	Conceptual model that defines which suppliers to involve in the product development process and in which phase.	Conceptual (experiences collected from an extensive research project / 225 companies in three continents).	Strong correlation between the adoption of ESI and the improved performance of the product development process.	In over 45% of the cases, the respondents disagreed about satisfaction regarding their efforts for integration. The interpretation is that companies perceive the importance of ESI but do not know how to implement it.	Process model to integrate suppliers in product development.
DOWLATSHAHI, 2000	Develop a conceptual model of ESI and try out the propositions of the model in a practical case.	Case study (a manufacturer of medical equipment and its suppliers).		The analyzed company placed the strongest stress on the tactical and operational mechanism of this integration. Little emphasis was given to the strategy, which may be the cause of the difficulties found in this case.	Conceptual model of the designer-buyer-supplier relationship.

Table 2 – Different types of suppliers - Kamath & Liker (1994).

Source: KAMATH & LIKER (1994)

Type of relation	Description	Responsibilities during product development
Partnership (Complete service supplier)	Relationship between equals.	Delivery of subsystems; Suppliers act as a "weapon" for the buyer; They participate in all the phase, including the pre-concept phase.
Mature (Complete systems supplier)	Buyers hold a superior position; Suppliers have a significant responsibility for the buyers' goals.	Complex assembly; Buyer provides specifications; Suppliers develop the system and may suggest alternatives to the buyer.
Initial	Buyers present their needs and suppliers attempt to respond to the demand.	Simple assembly; Buyers specify their design requirements and suppliers meet them.
Contractual	Suppliers are used as an extension of the buyers' manufacturing capacity.	Standard commodity or components; Buyers choose from a catalog and suppliers produce.