Effects of product development decision-making process on the supply chain

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Abstract: The constantly changing markets, company competitiveness, and the complexity in new products development are forcing companies to reconsider their strategic approach to the product development process. Product development decision-making related to product modularity, component commonality, and design re-use is important for balancing costs, responsiveness, and quality, including key product development process objectives. However, an organization's ability to develop new products through technological responses and their ability to meet customer needs does not guarantee the survival of market stability. Today, business success is dependent on the companies' strategic relationships with their customers and suppliers, to create value for developing products and to obtain a better market-share. Within this setting, the present paper aim to assess the effect of the product development decision-making process on the supply chain, in five Brazilian companies. This assessment is based on a reference model for the product development process in a Supply Chain Management environment.

Keywords: product development process, supply chain, reference model, life cycle management.

1. Introduction

The application of concurrent engineering for integrated product and process organization in the 1980s and 1990s provided a competitive differential for companies. It represented an improvement in the flow of information and a decrease in the time and cost of product development (CLAUSING, 1995; HARTLEY, 1992). The importance of integrating the design of product development and manufacturing processes is well recognized and various concepts have been proposed including design for assembly, design for manufacture, design for operability and other designs for excellence (DFX) (HUANG, 1996). In addition to concurrent engineering there has also been an increasing, and somewhat parallel, emphasis on synchronizing supply chain management (SCM) decisions with product development process decisions (HULT; SWAN, 2003). Factors motivating this emphasis are an elevated recognition of several inter-related factors, outsourcing of both manufacturing and design activities (SOBRERO; ROBERTS, 2002), involvement of suppliers in the product development process (MCIVOR; HUMPHREYS, 2004), and managing the buyer-supplier interface in product development (HARTLEY; ZIGER; KAMATH, 1997). There are two elements 'design for' and 'design of' which have been the focus of many studies in this area (SHARIFI; ISMAIL; REID, 2006). However, there are many questions which remain unanswered. For example: What is product development process decision making and what are its subsequent effects on the supply chain? What are the trades-offs between the product development process and the supply chain management? What are the critical points in the product development process for supply chain management?

Considering these issues, the current paper, applying the activities and tasks of the reference model proposed by Santos (2008), assesses the effects of product development process decision making on the supply chain in five Brazilian companies.

This paper is organized as follows: the literature review section provides a synthesis of the relationship between the supply chain management and product development process. The case study analysis, results and conclusions are then reported.

2. Literature review

As mentioned above, this paper aims to merge the concepts of supply chain management and the product development process, and to highlight the importance of reference models. The main activities and tasks of the reference model for the product development process in an SCM environment proposed by Santos (2008) will then be applied.

2.1. The relationship between concepts of supply chain management and the product development process

Traditionally, the concept of the supply chain refers to the flow of the transformation that products undergo from the raw material stage up to the delivery of the product to the consumer, focusing mainly on the flow of material. Due to an increase in the importance of the information and financial flows, and the adding of value in the supply chain, the concept of supply chain which best portrays the relations between product design and supply chain is the concept of supply chain management presented by Lambert (2004) and Handfield and Nichols Jr. (2002).

Supply chain management (SCM) refers to the management of relations between companies through their business processes, in order to create a system of value. Through this system the maximization of potential synergies, a decrease in wastage, and an increase in the efficiency and effectiveness of the business processes is sought, with the aim of adding value for the clients and stakeholders, making the supply chain more competitive.

Handfield and Nichols Jr. (2002) and Lambert and Cooper (2000) present the product development process as one of the business processes in the supply chain management, as shown in Figure 1.

In Figure 1 a simplified structure of the supply chain is presented. This illustrates the flows of information, products, finances, the business processes of the supply chain, the diversity of knowledge domains, in the upstream direction (network of suppliers) and in the downstream direction (network of distributors), the supply chain and the internal organization (internal suppliers).

The activities in the business processes of SCM are influence by several variables, such as the type of product, the commercial life cycle phase of the product, the changes required by the clients, launching of new technologies, regulation pressure and the market competitors, among others. These vary over time, thus imposing changes on the strategic objectives of the business processes which comprise the SCM, leading to the need for synchronization and convergence of the decisions in the SCM business processes (LAMBERT, 2004).

The product development process as a business process in the supply chain requires planning, execution and control of the supply chain activities, in a sustainable and competitive way (LAMBERT, 2004). Thus, it interacts with clients and supplies – internal and external to a company, through the activities of the business processes. The sharing of information and knowledge between those involved aids the creation of a system of value with the aim of fulfilling the different

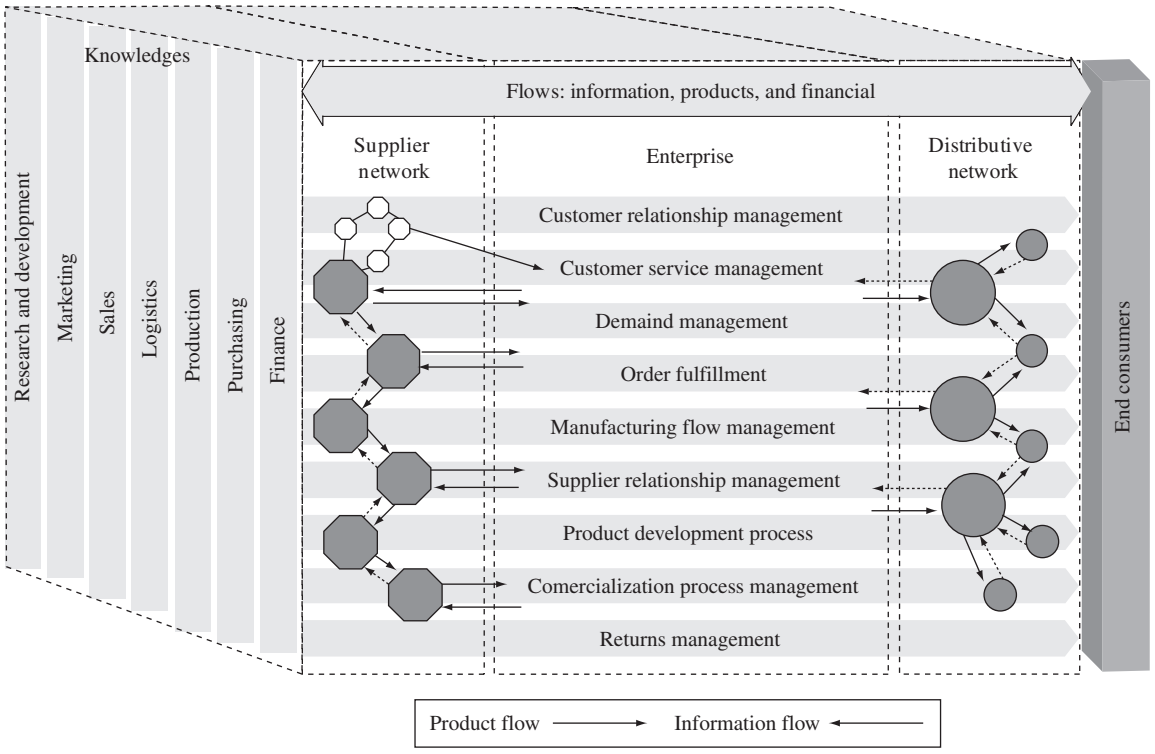

Figure 1. Model for supply chain management. Source: adapted from Handfield and Nichols Jr. (2002) and Lambert and Cooper (2000).

requirements during the product development process (HANDFIELD; NICHOLS Jr., 2002; LAMBERT, 2004).

2.2. The product development process and reference models

The product development process (PDP) includes managerial and technical aspects in which an organization transforms market opportunities and information on the technical possibilities to be used in the production of a commercial product. This process includes the design and development of a new product that is coherent with the product life cycle, starting from its planning and finishing with its discontinuance and withdrawal from the market (ROZENFELD et al., 2006).

The concept of a reference model has been primarily investigated by the German business information systems community. A reference model is a generic information model with a variable application context. Based on a certain reference model, multiple model applications can be obtained (FELDHUSEN; BUNGERT, 2007).

Vernadat (1996) defined a reference model, as a partial (or not) model that can be used as a baseline for products and the evolution of particular models. A critical point of a reference model is the building of a holistic vision of the process, regarding its activities, resources, organization and information flow, as well as their interrelationships.

Furthermore, Amaral (2002) considers that the modeling process contains specific procedures for different situations and modeling types, as shown in Table 1.

The reference models can also be qualified as generic, when applied to a certain industrial sector (ROZENFELD et al., 2006). Rozenfel et al. (2006) proposed a reference model for a product development process through the integration of the knowledge of three research groups (ROZENFEL et al., 2003). This knowledge integration involved the merging of the methodologies, case studies, models and better practices developed in recent years by the research groups involved (SANTOS, 2008).

Also, in Rozenfeld et al. (2006) the authors present the PDP involving all of the life cycle phases of a product, that is, the authors introduce the concept of Product Life Management.

2.3. Reference model for the product development process in an SCM environment

The reference models developed by research groups in Brazil are consolidated sources of information on how to conduct and structure the PDP internally in companies. They have served as a basis on which to establish the internal connectivity.

On the other hand, there are a great number of studies which report the importance of the involvement of the clients (WOODRUFF, 1997; VERYZER; MOZOTA, 2005; KLEEF; TRIJP; LUNNING, 2005; MASCITELLI, 2006) and suppliers (SANTOS; FORCELLINI; KIECBUSCH, 2007) in the PDP, extending the product development process to beyond the boundaries of a single organization.

Thus, the PDP in an SCM environment can be understood as an SCM business process, in which a group of companies in a supply chain, through integration and management of their activities seek to meet the requirements of the end clients, by way of the development of products and services, considering the requirements, possibilities and technological restrictions of the supply chain (SANTOS; KIECKBUSCH; FORCELLI, 2006; SANTOS, 2008).

In order to represent the knowledge involved in the reference model in a PDP in an SCM environment the IDEF0 modeling method was used. However, due to the difficulty in representing all perspectives of the modeling in a single model, it was based on the BPMN (Business

Table 1. Types and situations for the modeling methodology.

Basic type of model	Characteristics	Situation	Description
Reference	Its application is wider and more general. It can be used for the comparison of specific models.	New formalism	Designs where there is a reference model described and a formalism and transcription to the framework is desirable.
		Totally new	When the reference model is being developed specifically for the situation without being based on any process model.
Specific	Represent and/or are used by a specific company or system in a specific situation.	Process improvement	When a model better than the current one is desired for the process.
		New process	When dealing with a new model for the process, when there is no previous model for the process.
		Installation of engineering systems	When it is desirable to improve the existing model applying new informatics tools.

Source: Adapted from Amaral (2002).

Process Model Notation) standard to represent the different perspectives of the model.

Figure 2 illustrates a holistic view of the reference model for a PDP in an SCM environment.

Figure 2 shows the main outputs of the initial phases of the product life cycle related to the relationship with the client, product development process and relationship with the supplier. The outputs are generated by decisions related to the product design and the supply chain design.

The design of the supply chain, the design for the supply chain and the product architecture were the elements used for the synchronization of the decisions of the PDP with the SCM (SANTOS; FORCELLINI, 2007; SANTOS, 2008).

The different sizes of gears, shown in Figure 2, are analogous with gear systems. For the delivery of the end product to the consumer, a great number of decisions are made during the product life cycle, involving many knowledge domains. The decisions are of both a strategic and operational nature. Some relate to restrictions and possibilities related to the product characteristics, such as the number and complexity of components and the use of standardized and modular components. Other decisions relate to the resources available in the organization and in the supply chain to carry out the activities.

The decisions related to the product architecture have an effect on the whole life cycle of the product, that is, the structure which is initially selected for the product will affect the organization of the PDP activities and other SCM processes, for example, the participation of suppliers and partners in the PDP.

In relation to the phases of the model, ideas for new products are generated in the strategic planning phase of the product. From the business perspective, analysis of all of the product life cycle phases is carried out, with the aim of creating ideas and opportunities for new products and the existing resources in the supply chain in order to satisfy the requirements of the market and the company.

In the planning phase of the product design, the design problems related to the new product are divided into sub-problems, so that they can be more easily understood and solved. For this, before the generation of the product concept, target specifications are generated in the information design phase. In this phase it is necessary to understand the product design problem, to identify the clients along with their needs and restrictions, and to determine the possibilities for the product.

In the conceptual design phase, solutions to the problems of the product design are generated and based on the solutions offered by the supply chain. In the detailed design phase, the final architecture of the product is designed, with its components and subsystems and the final configuration

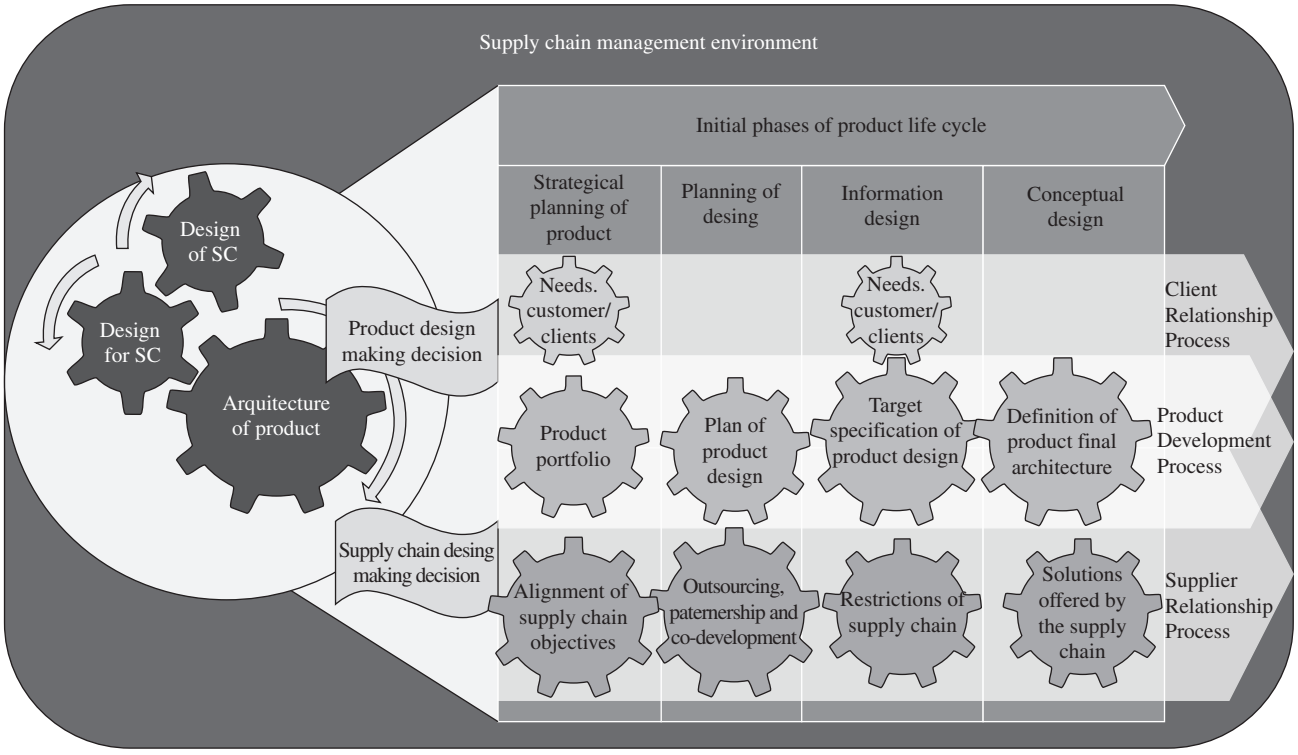

Figure 2. Holistic view of the model for a product development process in an SCM environment.

of the supply chain is determined which will give support to the product.

The complete model is composed of 56 mechanisms which aid in the carrying out of tasks, some of these being complementary for the carrying out of the same task, 171 outlets, most being of the activities described in the model relating to the pre-development phases (SANTOS, 2008).

3. Case studies in companies

The initial proposal for the case studies in companies aimed to evaluate the practices used and compare them with the proposed model for the PDP in the SCM environment, in order to carry out an analysis of the effects of the PDP decisions made on the supply chain. However, some barriers were encountered. The first two were related to the time available and the time of knowledge transfer to the companies. Another (more difficult to resolve, and which could minimize the problems of the first two) relates to the resistance to participation from the people involved at the company, mainly, at the more strategic levels.

Due to these barriers, two questionnaires were applied with different focuses, but which were consistent with the initial proposal. The first questionnaire with more open questions focused on decisions related to the product architecture and the design for the supply chain. The second questionnaire with more closed questions focused on the links between the outsourcing process and the product development process.

In order to guarantee the reliability of the data collected, the desired profile of the participants in the research was defined, as shown in Table 2.

Table 3 illustrates the main issues addressed during the field research.

3.1. Companies studied

The companies studied act in the following sectors: household appliances, metal-mechanical, automobile and industrial automation, four of them acting globally and one nationally. In relation to the supply chain, three of them act as a primary level supplier and interact with the end client and two are secondary and fourth level suppliers. All of the companies are large, according to the classification provided by IBGE (*Instituto Brasileiro de Geografia e Estatística* - Brazilian Institute of Geography and Statistics).

During the information surveys, the specialists from the companies were asked to give a description of examples of designs. However, this information is protected and cannot be revealed. Thus, the results of the research carried out at the companies are based on more than one product design and on previous experience.

3.2. The results of the study carried out at the companies

In the companies studied it was observed that there is a wide gap between the business and technical areas and also a lack of integration between the product design areas and the areas of the company suppliers.

In relation to the product architecture, when asked how they would define their modules to comply with the mass production strategies to improve the performance of the supply chain, it was identified that the strategies were based on the definition of functional modules, that is, the grouping of functions to fulfill the client needs. However, the closed questions showed that the main motivation for the use of the modularization strategy was related to the reduction of costs in the supply chain rather than meeting the client needs.

The questions regarding the making of decisions related to the product architecture and the product modularization process indicated that the main deficiencies are the mechanisms used to evaluate the effect on the supply chains. The most notable of these are:

- Added-value analysis: this generally includes only financial analysis, and other economic aspects, such as the main competences needed to add value for the

Table 2. Desired participant profile for the carrying out of the research.

Desired profile	Descriptions
Sectors	An attempt was made to explore sectors outside the automobile sector. There is a large volume of studies concentrated on the automobile sector, and the other sectors, such as household appliances, are less explored. However, a company may be part of more than one sector, such as: telephone, household appliances and automobile sectors, depending on its position in the supply chain.
Company	1. Launching of products on the market with a certain frequency. 2. The company has a formal product development process. 3. Mass production or the company is seeking mass production. 4. Considered an industrial benchmark by the industrial and academic community.
Participant	1. Knowledge of the product development strategies of the company. 2. More than five years knowledge of the development of products. 3. Knowledge of the decisions regarding how the product is assembled or manufactured. 4. Holds a management position (decision making). 5. Knowledge of the PDP and supply chains.

Table 3. Main issues addressed during the interviews at the company, within the context of PDP in an SCM environment.

Main theme	Method	Issues addressed
Product Modularization	Field research: semi-structured questionnaire with open questions applied in the company.	• Reasons for a more or less modular product architecture. • The critical factors in making decisions on the modularization of products during the PDP. • Level of product production, convenience of the standardization and outsourcing, analysis of product platforms and their relation with the product architecture. • DFX explored in the modular design.
Linking of the outsourcing process with the PDP	Field research: structured questionnaire with open and closed questions, sent by email, formatted in Excel spreadsheets.	• Motivation, advantages and risks for the involvement of the supplier in the PDP. • Factors for making decisions on the involvement of the suppliers in the PDP. • Implementation of the outsourcing process.

client, are not considered in the analysis;

- Deficiencies in the systems of analysis of the product complexity: these evaluate different parts of the product, with the same level of complexity generating many errors;
- Lack of mechanisms which consider the risk analysis of the involvement of the supplier in the PDP; and
- Deficiencies in the information of the road-map technology: the initial information of the road-map technology collected during the strategic planning are at a very abstract level and lead to errors in the subsequent technical translations.

The field research showed that the main motivations for the involvement of the supplier in the PDP are related to the cost reduction, and not necessarily the design of a new product.

The main aspects considered in the decision making regarding the involvement of the suppliers in the PDP described by companies were: essential competences, legal aspects, internal and external costs, intellectual capital costs, product reliability, logistic capability, current and future technologies of the supplier, current technology of the company, installed capacity, time reduction and mutual gain.

However, when the companies were requested to analyze the number of failures (cause of losses in time, quality and resources during the process) in relation to the involvement of the supplier in the PDP, a large number of failures were identified, which partially affected the product design, due to problems related to the involvement of the supplier in the PDP.

The PDP, according to some leaders of the companies studied, does not lie within the scope of the SCM. However, these leaders recognize that the value given to the different elements involved in the supply change will be dependent on the decisions made in the initial phases of the PDP.

It can be readily noted that the difficulty in understanding the PDP as an SCM business process was associated with a difficulty in understanding the concept of the business process and the reach of the PDP.

The companies which participated in the study recognized that the making of decisions related to the product architecture have an effect on the future business opportunities in the chain. They highlighted that the decisions regarding the strategic partnerships and network formation (chain design) are critical factors. The physical interfaces still represent a bottleneck in the selection of the actors involved in the supply chain, the selection of strategic partners, and the delivery of the modules which will be delivered to the end client.

On the other hand, the companies studied recognized that there are deficiencies in the mapping of the business processes with a focus on the product for the client, mainly the lack of the use of adequate mechanisms to aid in the evaluation of the effect of the PDP decision making in an SCM environment.

4. Conclusions

This paper reports the results of a field study carried out in five companies with the aim of identifying the effects of the PDP decision making on the supply chain. The study was based on a reference model for the PDP in an SCM environment. The field study in the companies showed a large gap between the theoretical reference proposed and the reality of the companies. Some gaps were due to a lack of integration between the business and technical areas of the company for the making of decisions related to the development process and a lack of appropriate mechanisms for the decision making.

The making of the main decisions which will affect the supply chain occurs in the strategic planning phase of the product. The survival of the companies is generally not based on a single product, but on a variety of products which can meet the client expectations. Thus, the choice of the architecture of the product portfolio involves the evaluation of the production, modularization, standardization and outsourcing strategies.

Within the context of more integrated companies, the company has total control over the decisions involved in the product development, such as the decisions regarding the architecture being more or less modular. However, in other types of supply chains the organization may not have complete control over the choice of product architecture or over the portfolio of products offered. This will depend on the position of the company in the supply chains of which they form part.

This means that before proposing a design for a family of new products, a knowledge base needs to be developed to aid in the decision making. This involves the analysis of the product variety, the level of production of the products for the clients, an evaluation of the point in the chain at which the product can be produced, the analysis of the modularity convenience, identification of the need for new product platforms and the possibility of passing activities on to the suppliers.

To aid this process, the company needs to establish policies in advance which provide guidelines for the SCM business processes, such as policies related to the involvement of clients and suppliers in the PDP, to establish strategic guidelines which aid in aligning the internal and external objectives of the business processes which comprise the SCM.

The field study in the companies aided mainly in the adjustment of the model in the planning phase of the product design, in which the need to consider the design of more complex products, differentiate the suppliers from the collaborating partners, plan the passing on of activities to the suppliers and collaborating partners, and consider the needs of the collaborating partners in the initial phases of the product design, were included.

The study involved five companies based mainly on qualitative information, with a future opportunity for its application in a greater number of companies, a sectorial analysis and possible statistical evaluation. Despite involving a small number of companies, it revealed other future opportunities for the deepening of some themes, such as the development of a DFX with a strategic focus, the development of mechanisms to give support to companies in the evaluation of effects on the supply chain and the development of models for the PDP in more specific supply chains.

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