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THE IMPACTS OF PRODUCT ARCHITECTURE DECISIONS-MAKING ON SUPPLY CHAIN OF THE XIX COBEM

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Abstract. *The market's constant change, the competition among companies, the complexity required in the development of new product are forcing firms to reconsider their strategic in product development process. Product development decisions, such as product modularity, component commonality, and design re-use, are important for balancing costs, responsiveness, quality are important product development process objetives'. However, the organizations'ability to new product development by means both technological answers an their ability to meet customer needs does not guarantee the survival of market stability. Today, business depends on strategic relations with their customer and suppliers to create value for developing product and to obtain better market-share. Considering this problem, this paper examines the product archicture decisions-making and subsequent impacts on supply chain. From study of the effects of product archicture decisions-making on supply chain it was proposing the pratical model for assessement of the impacts of product archicture decision-making on supply chain.*

Keywords*: product architecture, supply chain, product development process, making-decisions*

1. INTRODUCTION

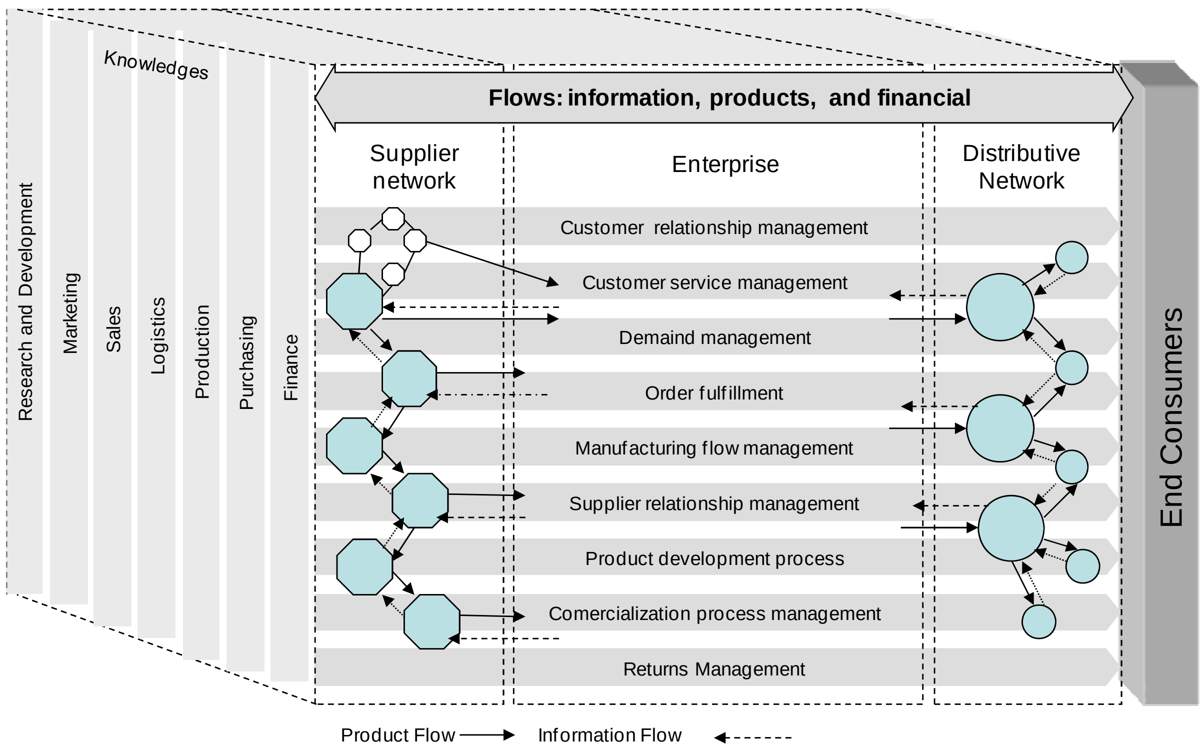
The approach of the product and process concurrent engineering, in the decades of 80 and 90, it was competitive differential for the companies. It was improvement of flow of information, decreasing of times and cost product development (Clausing, 1995; Hartley, 1992). The importance of integration product development process and manufacturing process design is well recognized and various concepts such as design for assembly, design for manufacture, design for operability and others 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). Motivating this emphasis have been elevated recognition of several inter-related factors, outsourcing of both manufacturing and design activities (Sobrero & Roberts, 2002), involvement of suppliers into product development process (McIvor & Humphreys, 2004), managing the buyer-supplier interface in product development (Hartley, Ziger, & Kamath, 1997). There are two elements 'design for' and 'design of' have already been focus of many researches in this area (Sharifi et al., 2006). However many remaining questions. For example, what are product architecture decisions-making and subsequent impacts on supply chain; what are trades-offs between product development process and supply chain management; what are critical points in product development process for supply chain management.

The research propose is to synthesize knowledge of existing theory about three elements 'design for', design of' supply chain and architecture into a new model for understanding and importance the impacts of product architecture decisions-making on supply chain. Section two introduces the concept PDP in context of SCM and presents three elements integration between PDP and SCM: architecture of product, design of and design for supply chain. Section three from a review of the literature some effects of product architecture decision making was identified. Section four presents a model with flows mains of information between product design and supply chain design making-decision in PDP and other model for involvement supplier into PDP. Conclusions are further research directions present in section five.

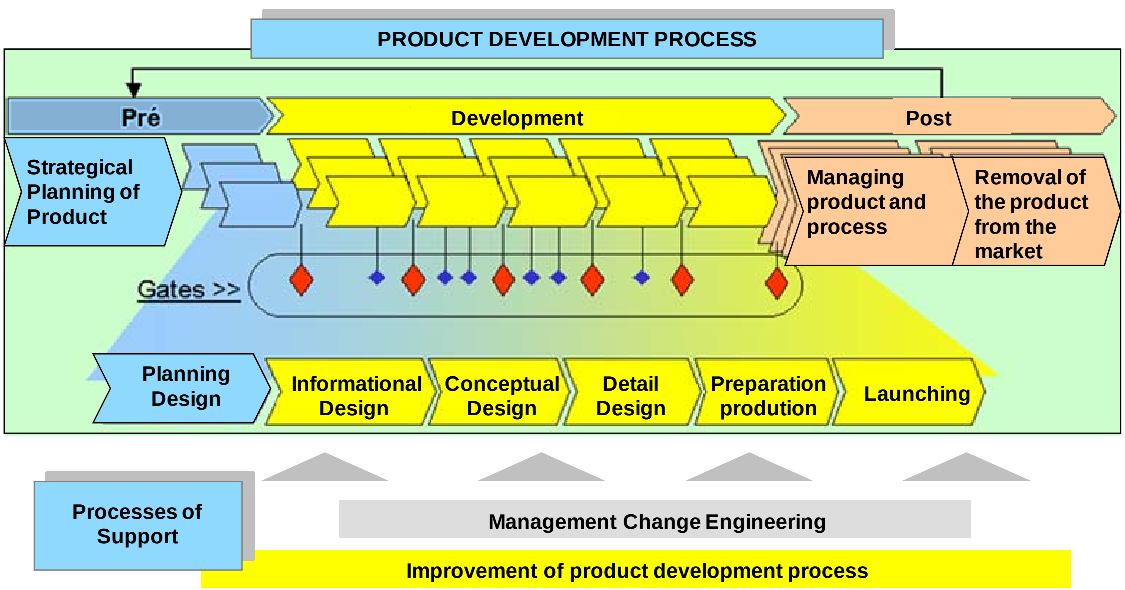
2. THE RELATIONSHIP BETWEEN SUPPLY CHAIN MANAGEMENT AND PRODUCT DEVELOPMENT PROCESS

Supply Chain Management (SCM) refers to management between companies by means of their business processes; where they seek to maximize potential synergy, reduce waste, increase efficiency and the effectiveness of business processes, with the objective of adding value for the clients and stakeholders, making the supply chain more competitive (Handfield & Nichols Jr., 2002; Lambert, 2004). Initially, the business processes were regarded as a way of integrating companies' corporative functions. Presently, companies seek to structure activities between the different members of a supply chain through the business processes, so as to make them manageable in the long run (Lambert, 2004). The PDP is one of business process of SCM (Lambert, 2004; Handfield & Nichols Jr., 2002). It is illustrated in Picture 1.



Picture 1. Model for supply chain management. Source: adapted of Handfield & Nichols Jr. (2002, p.39) and Lambert (2004, p.3)

PDP involves technical and management aspects, in which an organization transforms market and technical possibility opportunities into information for the production of a commercial product. This process includes the development of a new product in a way that is coherent with the product's lifecycle, which starts with its planning and ends when it is discarded or taken off the market (Rozenfeld et al., 2006). Aiming to supply a common reference, a holistic vision of the product development process, leveling knowledge within the different knowledge areas, a reference model for PDP was proposed, it is illustrated in Picture 2.



Picture 2. Reference model for product development process. Source: (Rozenfeld et al., 2006, p.44)

In Hult & Swan (2003) is shown a framework of interface of product development process and supply chain activities. It is illustrated in Picture 3. In this framework are shown six activities for product development process and ten activities for supply chain management. Subsequently, there are 60 direct interdependencies for research between product development process and supply chain management.

Activities of product development process	Activities of Supply Chain Management
	a. Selection and qualifying desired suppliers
1. Ascertaining new customers needs	b. Establishing and managing inbound logistics
2. Designing tentative new product solutions	c. Designing and managing inbound logistics
3. Developing new solution prototypes	d. Establishing and managing outbount logistics
4. Identifying and managing internal function/departmental relationships	e. Designing work flow in product/solution assembly
5. Developing and sustaining networks of linkages with external orgs.	f. Running batch manufacturing
6. Coordinating product design activities too speed up business processes	g. Acquiring, installing and maintaining process technology
	h. Order processing, pricing, billing, rebates, and terms.
	i. Managing (multiple) channels
	j. Managing customer services (e.g. installation and maintenance to enable product use)

Picture 3. Interface of product development process and supply chain management activities. Source: (Hult & Swan, 2003).

‘Design of’ supply chain, ‘design for’ supply chain and product’s architecture are important elements for research in interface of product development process and supply chain. These elements were identified from a review of the literature.

2.1. Product Architecture

Ulrich defines the product architecture as “the scheme by which the function of a product is allocated to physical components” (Ulrich, 1995). With to physical complex mechanical and electromechanical products (automobiles, appliances, etc.), which usually consist of a substantial number of components, the product architecture encompasses the information on how many components the product consist of, how these components work together, how they are built and assembled. It is including the arrangement of functional elements, the mapping from functional elements to physical components, the specification of the interfaces among interacting physical components (Ulrich, 1995)

Depending on the interdependencies shared between components and respective interfaces, product architectures can vary form integral to modular. In integral product architecture, as one-to-one mapping between functional elements and physical components of product is nonexistent, and interfaces shared between at components are coupled. Changes to one component cannot be made without making changes to other components. Contrary to integral product architectures, modular product architectures are used as flexible platforms for leveraging a large number of product variations (Mikkola, 2003).

It also makes standardization possible, which is essential to achieve the economy of scale. There fore, using the modular product architecture, variety can be created by combinations of component building products (Pahl & Beitz, 1996). In Pahl & Beitz (1996) also discussed the advantages and limitations of modular products. In Huang (2000) exposed five categories of modularity (i.e component, swapping, component sharing, fabricate-to-fit, bus and sectional modularity) and mostly refers to the product archicture as physical structures in terms of physical parts or components. However, little effort has been devoted to the implications of archicture with respect to functional features and design parameters, especially in terms of systematic planning of modular architecture starting from the early conceptual design stage. In addition, research mostly focuses on product archictures and modular product design in the context of a single product. Since organizations increasingly develop product families to offer a large variety of products with low development and manufacturing costs, the architecture for product families becomes a major concern (Tseng & Piller, 2003, p. 125) .

Product family architecture involves systematic planning of modularity and commonality in terms of building blocks and their configuration structures across three consecutives domains, namely the functional view- as seen form customer, sales, marketing viewpoints; the behavioral view - as seen from the product technology or design enginner perpective; and the structural view – as seen from the fulfillment or manufacturing and logistic perpective (Tseng & Piller, 2003, p. 126). In Otto & Wood (2000) is shown the necessity to develop the product architecture and family with the synchronization of multiple views such as those from customer needs, function structures and physical archictectures. It is call of ‘product portfolio architecture management’.

2.2. Design of Supply Chain

It is generally known that approximately 80 per cent of the manufacturing cost of a product is determined by the design of the product. The outcome of efforts to improve product's performance in supply chain after product launching is very small-time (Simchi-Levi et al, 2003, Appelquist et al., 2004). However, the most of design of supply chain literature talking about product after product launching. It is approach in manufacturing process. Traditionally the supply chain literature does not comprise the product development process.

Actually, the design of supply chain is the collection of process that translate ideas for products into product definitions – such as recipes, BOMs, work instructions, workflow – and develops or re-uses the process and infrastructure for selling, fulfillment and support of the product (Hunsche, 2006). This concept is more inclusive than traditionally concept (i.e. Slack et al., 2002; Simchi-Levi et al., 2003).

According to Appelquist et al. (2004) design of supply chain covers two main dimensions including pre-determining and reengineering, and optimization and continuous improvement. These two dimensions follow an analogous process that starts from design requirement analysis and through to the set up of supply chain objectives. Design of supply chain can be considered as composed of five general (Sharifi et al., 2006): understanding of market requirement, and the current situation of the supply chain; determining supply chain performance attributes based on an analysis of customer requirement and the current situation of the supply chain; determining supply chain performance dimensions that stand for the areas where the supply chain attributes can be decomposed to more concrete performance dimensions; translating supply chain dimensions into supply chain functions converting the conceptual supply chain to an actual supply chain; designing and examining all the components and aspects of desired supply chain against the market requirement and current situation. This is the most complex and consequently costly a time consuming.

2.3. Design for Supply Chain

Product design for supply chain management means building products that thrive in and enhance your supply chain architecture. Simply 'giving customers what they want', while fundamental to customer satisfaction, is rarely enough. Companies must be able to give customers the right products in the most resource-effective manner, without sacrificing quality or service.

From a review of the literature, design for supply chain can be considered as set of principles including variety management, logistic enhancement, commonality and reuse, postponement, tax and duty reduction, environment and take-back. For example, in Martin and Ishii (2002) describe a step-by-step method that aids companies in developing such product platform architectures. They are used the concept of design for variety (DFV). Design for variety is a series of structured methodologies to help design teams reduce the impact of variety on life-cycle costs of a product. (Martin & Ishii, 2002)

The design for manufacturability (DFM) literature suggests reducing the number of types of parts. In fact, there are many DFM rules that are related to the idea of reducing parts. One may consider not only the variables, number of parts, and number of types of parts, but also the following: number of moving parts, number of part interconnections, number of fasteners, number of tabs, number of rivers, number of press fits, number of labels, number of sub-assemblies, number of types of subassemblies, number of product functions, number of product features, number of manufacturing processes, and many more (Boer & Logendran, 1999).

In addition to these 'number of' variables, as suggest in the DFM literature, products that are very large or very small are difficult to work with and manufacture. The size of the product, therefore, may affect product development cost and time-to-market. Other attributes such as product or part weight, reflectivity, magnetism, and heat and/or electrical conductivity may also affect cost and time-to-market (Boer & Logendran, 1999).

There are many other variables that one might consider using after reading through the DFM literature (Bralla, 1996).

Standardization of parts and materials is a fundamental aspects of DFM, which can simplify product development efforts, lower the cost of parts and materials, drastically reduce material overhead costs, simplify supply chain management, improve availability and deliveries, raise quality, improve serviceability, and support lean production, build-to-order, and mass customization (Anderson, 2004, p. 127). The standardization of parts and material has influence on cost reduction – purchasing cost, inventory cost reduction, floor space reduction, overhead cost reduction; quality – product quality, continuous improvement, supplier reduction; flexibility - steady flows, eliminating setup, inventory reduction, internal material logistics, breadtruck deliveries, supports lean production, BTO, and Mass customization; responsiveness – build to order, parts availability, quicker deliveries from suppliers, stronger suppliers (Anderson, 2004).

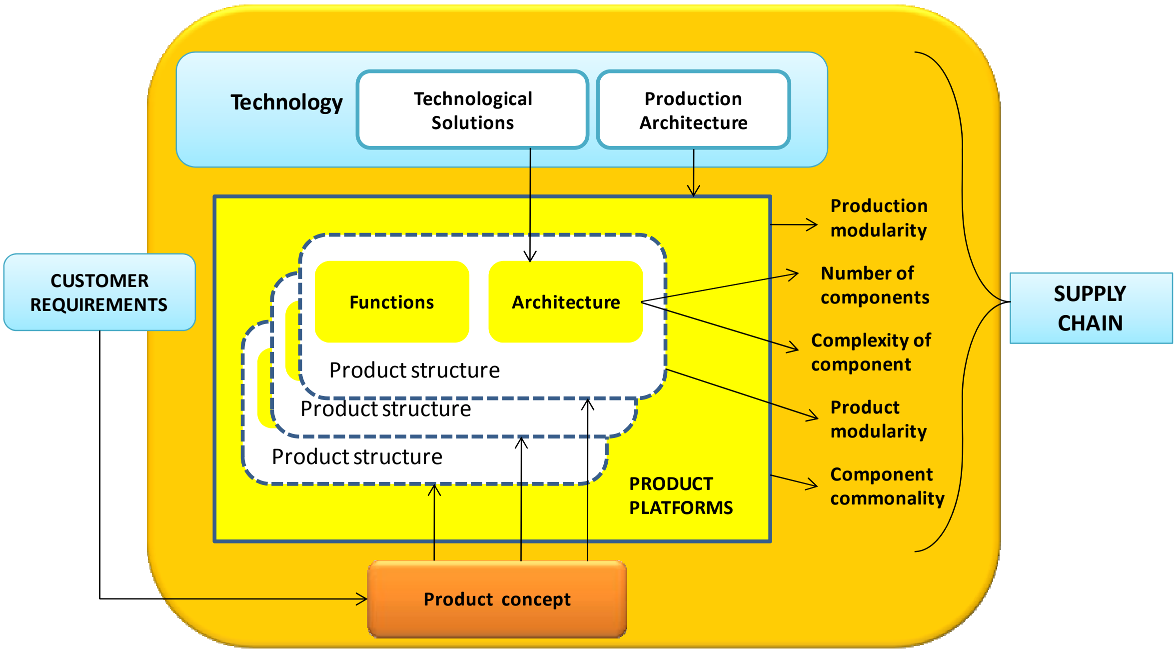
3. SOME IMPACTS OF PRODUCT ARCHITECTURE DECISIONS-MAKING

From a review of the literature some impacts of product architecture decision making was identified. In the product development domain, decisions with rather long-term horizons range from capability development of design engineers to the selection of locations for development facilitate to the formation of strategic development patterns. Product related decisions comprise questions of product functionality, product line variety, material choices, and product styling (Pahl& Beitz, 1996). Organizational decisions include the number and size of design teams, whether these teams are cross-functional, methods to steer tem group processes, and tools to plan product development milestones, sequence, and the degree of overlap (Rozenfeld et al., 2006). Individual product characteristics have found to affect many of project teams, for example, are in most cases not independent of number, size, and composition of product's components. The structure that is initially selected for the product will affect the task structure of the product development organization, and the task structure, in turn, contributes to the organization's performance (Ulrich & Eppinger, 1996). The underlying reason is that the task structure determines the interaction and communication patterns of the development teams. For example: reducing product complexity into fewer modules has been identified as a way to shorten product development process time.

Decisions products variety affects production investment, examples of these decisions are the size of production capacity, the type of manufacturing processes, or locations of production facilities. A major class the decision in process domain is the selection of number and type of processes that will be used to manufacture the product. These decisions are not independent of product architecture characteristics such as complexity of the individual components, number of components, extend to which components can be reused across product families, or degree of coupling between components (Tseng & Piller, 2003).

In supply chain domain, decisions include number and location of logistics facilities, contractual relations with suppliers, long-term sourcing, arrangements, and postponement, service levels, delivery schedules, vehicle routing. Individual product architecture characteristic that have been identified affect these decision are the degree of commonality across components, the way in which the components interact with each other, and type of interface between the components (Handfield & Nichols Jr., 2002; Simchi-Levi et al., 2003).

In picture 4, it is illustrated cause and effects decision-making in design for supply chain domain.



Picture 4. Cause and effects of decision-making in product development domain.

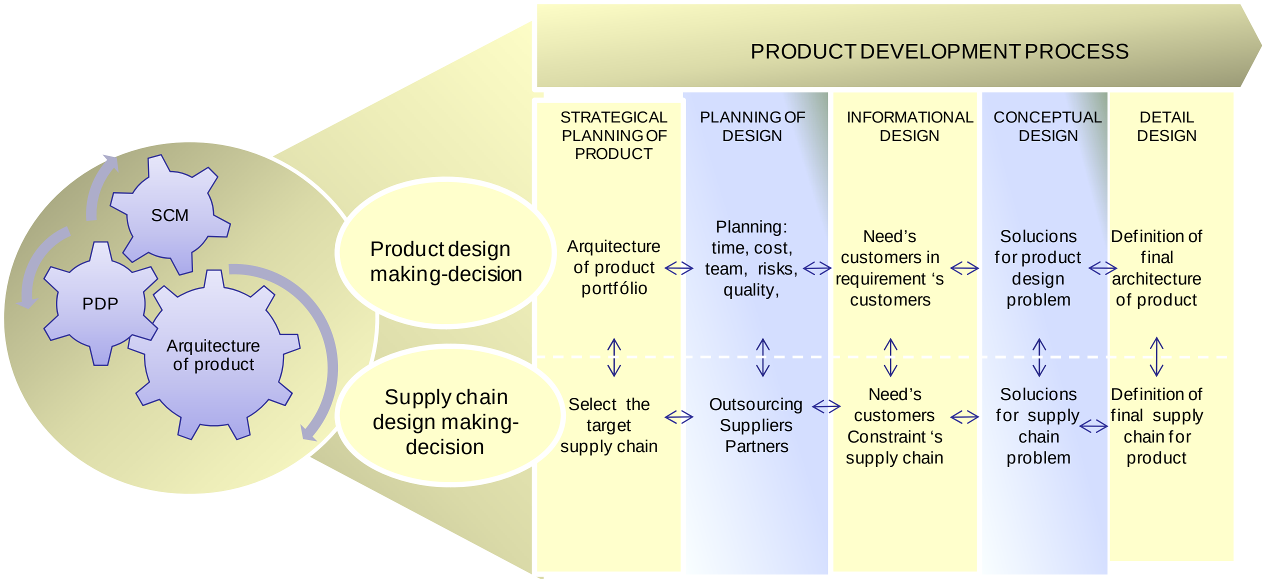
4. THE MODEL FOR PRODUCT ARCHITECTURE MAKING-DECISION IN PDP

From appraisal of the elements, 'design of' supply chain, 'design for' supply chain and product's architecture. It was proposed um model with main flows of information between product design and supply chain making-decision in PDP.

The picture 5 is illustrating the model for product architecture making-decision in PDP. It is showing main flows of information between product design and supply chain design making-decision in PDP.

To move a product from the initial to its arrival at the customer requires many decisions on design and operation in the three domains product, process a supply chain. These decisions are of strategic and operational nature, and many of these decisions are constrained, or enabled, by product characteristics such as the number and complexity of components, commonality, or product modularity.

Before product can be developed into a concept or even into a reasonable set of specifications, it is important to develop the larger corporate environment within which the product exists. It is development in 'product strategic planning phase'. Essentially this phase is making-decisions about product portfolio architecture.



Picture 5. Main flows of information between product design and supply chain design making-decision in PDP.

Companies typically do not survive based on revenues from as single product but rather offer a variety of closely related products, all of which must be evolved over time. It is critical to make effective configuration choices for the corporate set of products (Otto & Wood, 2000, p. 304). A 'product portfolio architecture' is the system strategy for laying out components and systems on multiple products to best satisfy current and future markets needs. It is used market demands as the basis for differentiating portfolio architectures. Selecting the product portfolio architecture is complex and critical. Much of the content of subsequent product design activity is determined by the decisions made at this stage.

One usually approaches to selecting product portfolio architecture is base it on customer need variety - mass customization strategic (Tseng & Piller, 2003). The applications of mass customization imply the identification of product components, standardized modules, permissible product configurations and efficient product processes. Essentially the trade-off of variety catering to customization and low costs of variety fulfilment. Development product families has been recognized as effective means of achieving economies of scale in order accommodate and increasing product variety. The concept of architecture of product family is proposed to capture the underlying logic a product family a thus to support product variant derivation. Modularity, commonality and variety are important concerns in product family development. The generic product structure and variant derivation mechanism is the core of architecture of product family based product family design (Tseng & Piller, 2003, p. 156).

Others approaches to selecting product portfolio architecture can be based on target supply chain – the performance goals that create the specific context for optimizing the performance of the selected supply chain (Handfield & Nichols Jr., 2002).

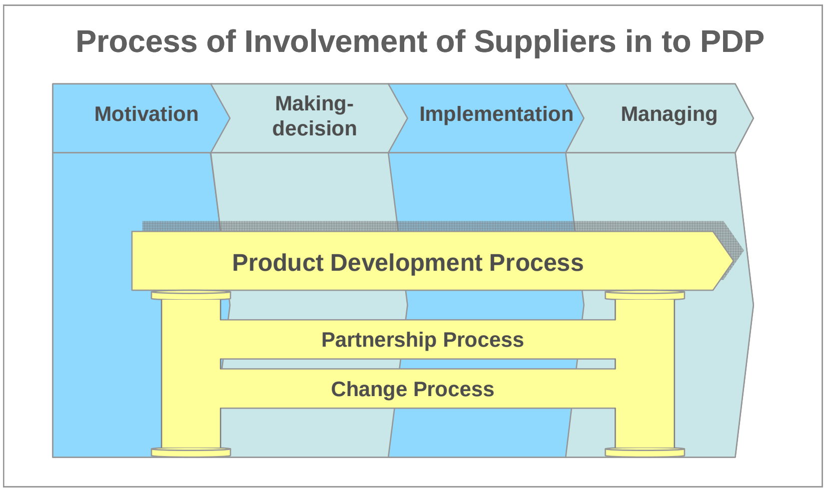
The decisions the product portfolio architecture will organization decisions of product development process – the structure that is initially selected for products will affect the task of the product development organization, and the task structure, in turn contributes to the organization's performance, for example: outsourcing and involvement of suppliers into PDP. These decisions are incorporated in phase de 'planning of product design'.

Based on the studies supplier involvement in PDP, integrating of outsourcing process in to PDP, and the PDP reference model proposed by Rozenfeld et al (2006), a model for the supplier involvement in PDP process is presented in Picture 6, as a means for supplier involvement in PDP (Santos & Forcellini, 2007). It aid planning of the product development activities in supply chain.

The process of supplier involvement in PDP is divided in 4 stages: motivation, decision making, implementation, and management. Partnership and change processes form two pillars for performing activities.

The company's internal and external connectivity are inserted in the model's stages. In this paper connectivity is understood as information technology resources, like the ones that allow real time connections, computer to computer, increasing companies' efficiency. By means of reduction of time and routines necessary for performing an activity. It involves the integration of the information flow with the supply chain to create value for the final consumer.

Considering a (individual) company, included in the network are the suppliers (upstream) and the distribution channel (downstream). The internal suppliers of the same company are included as well.



Picture 6. Conceptual model for supplier involvement in PDP.

Based on the study of the art of supplier involvement in PDP the implementation stage was divided in a quadrant square, illustrated in Picture 7.

The first quadrant focuses on strategy activities in the partnership process: the main activities in this group involve the definition of guidelines for supplier involvement in PDP based on company strategies.

The second quadrant focuses on strategy activities in the change process: the main activities involved in this group aim to define company structure to carry out the change process in the company to have supplier involvement in PDP.

The third quadrant focuses on operational activities in the partnership process: the main activities in this group involve the definition of technical activities for supplier involvement in PDP. Focus on (technical) engineering activities is the main characteristic for supplier involvement in PDP based on the established strategic activities.

The fourth quadrant focuses on operational activities in the change process: the main activities involved in this group are the definition of methods and tools for implementation of the change process in the company to supplier involvement in PDP.

	Partnership Process	**Change Process**
Strategic Activities	1st Quadrant The main activities is this group involve the definition of guidelines for supplier involvement in PDP based on company strategies	2nd Quadrant The main activities is this group aim to define company structure to carry out the change process in the company to have supplier involvement in PDP.
Operational Activities	3rd Quadrant The main activities in this group involve the definition of technical activities for supplier involvement in PDP. The main characteristic is its focus on (technical) engineering activities for supplier involvement in PDP based on the established strategic activities.	4th Quadrant The main activities involved in this group are the definition of methods and tools for implementation of the change process in the company to supplier involvement in PDP.

Picture 7. Conceptual model for implementation of supplier involvement in PDP.

Before generation of concept of product, is to generate the technical specifications of the design. It is phase of ‘informational design’. To do so, it is necessary to understand what kind of problem the design has, who the customer are, what their necessities are, what requirements and restrictions the design has to produce the product. The principal method used in this stage is the QFD (Rozenfeld et al., 2006).

The concept generation process begins with a review of customer needs, highlighting the primary needs that are the initial focus. Ultimately, all the needs must be satisfied through concept generation. Yet the process begins by considering the most important needs first. Iteration in the process may then be used to create further concept for secondary or supporting functions. Based on the customer-needs focus, the design task is decomposed into sub-problems that may be more easily understood and solved. These sub-problems are of three forms: functional models, product architecture, and product portfolio. In each case, the focus is on what the product must do, not how it will do it (Otto & Wood, 2000, p. 414). Because of supply chain performance target will be to solve problems in constraint's supply chain, i.e., service and support for customers, type of material, type of modal and assembly of product.

In phase of detailed design includes definition of final architecture of product and final supply chain. Testing prototypes, distributing the information, such as contracts, work-instructions are activities this phase.

4. CONCLUSIONS AND FURTHER RESEARCH DIRECTIONS

The paper has presented a general model for synchronizing supply chain decisions with product development process decisions, illustrated in picture 5. Three elements were identified for synchronizing supply chain decisions with product development process decisions: design of supply chain, design for supply chain and architecture of product. The main relationships between three elements have been thoroughly analysed with reference to existince literature.

The model provides a system to understand how elements are influencing final architecture of the product. It is worth emphasising that product final archicture is influenced both product and supply chain strategies. There are many critical points in PDP for supply chain managemt. The main of them is product planning phase, in this phase making-decision about involvement of suppliers into PDP. The main trade-offs between product devolpment process and supply chain is informational design phase. It is between final customers needs and product design clients.

The proposed model in full detail includes others importants information as outsourcing process in PDP, involvement suppliers in PDP, parthenership process, change process, it was synthesized and ilustrated in 6 e 7 picture. In this paper approched more technical decision-making than orgazanization decision-making. The organization decion-making was published in Santos (2007). In addition, model in full detail includes a value stream map as tool of flow information and knowledge that are more easily tracked.

At moment, it is mapping the main flow information using the value stream map tool. The value stream map tool can help product architecture making-decision in three ways. First, they can use to focus on design decisions critical for product and supply chain under consideration. For a planned product and operation strategy, it can help to identify those architectures characteristics that need to be focused on during early product design to best serve that strategy. The second way in which the value stream map can help constitutes the reverse situations. It can help to explore the advantages and limitations of various operational strategies for given product architectures. The third, it to improve a supply chain' strategy planning capabilities over time. With help of scenarios the possibilities and limits of different product architectures could be explored.

The next step of the work will be the study of cases in companies.

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