The first stage of a proposal of a theoretical model for managing a new product development process

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Abstract: Developing products consists of a process that involves knowledge and various functional areas and presents a high degree of complexity and iteration in its execution. It is characterized by an intense flow of information, by a great number of people involved, and even by companies working together in an inter-firm collaboration. The literature presents various models and approaches to describe a new product development process. However, they usually do not adequately represent its dynamics. The aim of the present work is to describe the product development process based on the nature of its elements covered by the literature. Moreover, the purpose of the article is also to identify how the interaction among them occurs. A representative conceptual model of this process is proposed within two levels of integration. The theoretical model is based on six dimensions (strategic, organizational, technical, planning, control and operational) integrated in structural and operational levels. The paper also identifies what the elements that compose the operational dimension are and how the interaction between them can be characterized. In addition, some properties that affect the new product development process are outlined. The conceptual model presented attempts to meet the needs of a more adequate representation of the dynamics of new product development by integrating different perspectives and helps understand it. The paper also emphasizes the need for new studies with a detailed analysis of the interaction and the integration of the elements presented here.
Keywords: product development management, product design, new product development.

1. Introduction

New product development (NPD) is increasingly the key element to the company competitive advantage (BAILETTI et al., 1998) and long-term success (WHEELWRIGHT & CLARK, 1995). This is mostly due to the increase of international competition, the creation of fragmented markets with increased customer requirements and fast technological changes (CLARK & FUJIMOTO, 1991). KRISHNAN & ULRICH (2001) define new product development as the transformation of a market opportunity into a product available for sale, through a set of activities (ROZENFELD et al., 2006) executed in a logical way, sequentially or concurrently (DENKER et al., 2001).

The product development process presents several characteristics that differentiate it from other business process, as follow: high degree of uncertainty and risks in the activities; difficult to change initial decisions; the basic activities follow an iterative cycle; the creation and handling of a high volume of information and multiple requirements to be considered (ROZENFELD et al., 2006). For those reasons, the development of products represents one of the most risky endeavours of modern corporations (COOPER, 2001) and its management is one of the most difficult tasks in any organization (KERZNER, 2001).

Several models were created in the last decades containing rules, guidelines and procedures for managing product development (ENGWALL et al., 2005). The models initially described the process as a linear system, with discrete and sequential stages, while more recent studies consider that the development process evolves through stages, but with overlap and feedback loops (McCARTHY et al., 2006).

According to KLEIN (1995), the development projects became a collaborative entrepreneurship with highly complex interdependencies. In doing so, the search for more effective organizational patterns in the NPD process shall include a detailed analysis of how the development really occurs (CLARK & FUJIMOTO, 1991).

ENGWALL et al. (2005) affirm that models allow the communication inside and between projects, providing a common language and concepts. However, when dealing

with the ever changing practice, the focus only in new models is insufficient (ENGWALL et al., 2005) and the most used representations do not adequately describe the projects dynamics (DENKER et al., 2001).

Considering then the inadequate representativeness and applicability of theoretical models and frameworks to deal with the dynamics of the product development process, this paper aims at characterizing this process through a representation of its dimensions and the elements that compose it, besides analyzing the interaction among each part.

2. Research methods and techniques

This paper can be classified as a theoretical-conceptual research. The construction of its theory was based on a literature review, in which papers related to management, coordination, integration and decisions in the NPD process were gathered. To do that, a bibliography search in the following journals was initially conducted for the period from 1999 to 2006: **Journal of Product Innovation Management, Management Science, Research and Development Management, Production and Operations Management and Research Policy.** After that, relevant papers were identified by key-words containing the themes cited earlier in this section in the following databases: **emeraldinsight; extenza-eps; blackwell-synergy; sciencedirect.** Finally, other papers were selected by cross-reference, that with the above mentioned, have come up to 52 papers.

This research project can be divided into two main parts. In the first part, several ways of classifying the product development process were analyzed. Then, based on the previous analysis, a classification of the dimensions that comprise the product development process was proposed. The topics that compose each dimension were then grouped according to this classification. The second part of the literature review was directed to identifying the elements that characterize the development process itself and the way they interact. To do this, papers that have an empirical approach were analyzed. The analysis considered approaches and tools in which these elements are considered as well as the aspects related to the nature of information and the cognitive aspects, that refer to the implicit patterns in decision making.

3. Literature background

3.1. Approaches and classifications of the development process

According to CHENG (2000), the study of product development management subject, in a widely and in an integrated way is quite new. Since it consists of a vast knowledge field (CHENG, 2000) it can be classified in several ways. In the literature, several approaches were found and there is an overlap of themes in some areas.

Product development approaches can be classified according to an academic perspective (CHENG, 2000) that includes: marketing, organization, engineering and operations management (KRISHNAN & ULRICH, 2001). Another way of looking at new product development process is according to the perspective of the functional areas, that conceive NPD in a different way, thus complementary. Other emphases can be found in the product development literature, for example, in the use of methods and techniques. According to ENGWALL et al. (2005), models were created in the last decades and they include rules, guidelines and procedures to manage the development of projects with the objective of determining the project execution. These models are a representation of the main flows in the product development process.

CHENG (2000) presents a classification framework of most relevant topics in product development management. There have been proposed three dimensions: strategic, operational and performance evaluation of the product development. The strategic dimension is divided into two main topics, including subjects related to portfolio management, capacity dimensioning, and inter-organizational and inter-functional integration. The operational dimension is divided into the following topics: development process itself and the use of methods and techniques and the work organization, that refers to the aspects of team work and competence development, such as responsibility, authority, coordination, etc.

KRISHNAN & ULRICH (2001) propose an approach based on decisions. They affirm that while **how** products are developed differ not only across firms but within the same firm over time, **what** is being decided seems to remain fairly consistent. In this sense, they propose a classification that organizes the decisions into two categories: the decisions within the context of a single project and the decisions in setting up a development project. In one hand, the authors (KRISHNAN & ULRICH, 2001) divide the decisions within the context of a single project in four categories: concept development, supply-chain design, product design, and production ramp-up and launch. On the other hand, the decisions in setting up a development project are divided into three categories: product strategy and planning, product development organization, and project management.

Other authors in the product development literature have used the approach based on decision. MCCARTHY et al. (2006) consider three levels of NPD decisions: strategic, review and in-stage. The 'strategic' decisions are related to market and product strategies and portfolio management. The decisions in the 'review' level occur between stages, while 'in-stage' decisions refer to those in the operational level of each phase.

In the same line of thought, ANDERSON & JOGLEKAR (2005) classify the decision in four levels: strategic planning, tactical planning, operational planning and planning infrastructure. POWELL & BUEDE (2006), stem from the work conducted by KRISHNAN & ULRICH (2001), propose a division in two systems: the operational system and the development system.

From the classifications shown earlier, the strategic and the operational dimensions are explicitly cited in almost all of them (CHENG, 2000; KRISHNAN & ULRICH, 2001; ANDERSON et al., 2005; McCARTHY et al., 2006). Its concepts are also considered in the classification proposed by POWELL & BUEDE (2006). Other dimensions that can be also highlighted are the organizational and the project management that are cited in almost all classifications.

3.2. Approaches and concepts associated with the dynamics of the development process

The increasing complexity and the cooperative environment in the design process are requiring a more effective coordination of it (KLEIN, 1995). Coordination underlies many of the management problems in designing products rapidly and effectively (BAILETTI et al., 1998). The most used representations and techniques do not adequately describe the dynamics of the development process (DENKER et al., 2001) and this requires an analysis of how the development really occurs (CLARK & FUJIMOTO, 1991). Considering this, several authors are working on new approaches and concepts aiming at providing tools that will help in the coordination, integration and in the decision making in the development process.

BAILETTI et al. (1998) propose a 'coordination structure', an approach to model the organizational situations that considers the concepts of responsibility interdependence, social networks and shared objects. The approach that was proposed, according to the authors, provides the foundation upon which information is communicated and processed.

The concept of interdependence among decisions that, in a certain way, resembles the responsibility interdependence proposed by BAILETTI et al. (1998), is used by KRISHNAN & ULRICH (2001). They state that the coordination of decision making requires an approach that is driven by the intrinsic interdependencies among decisions, rather than being driven by attempts to bridge the extant functional structure; it also assumes that an organization manages uncertainty through information processing. They complement that the management of overlapping in concurrent design requires a detailed representation of the information exchanged between individual tasks and a deeper understanding of the properties of information.

DENKER et al. (2001) based their work on the Dependency structure matrix (DSM), proposed by STEWARD (1981), to deal with the information interdependence among tasks. The proposed approach has the objective of designing project plans that produce greater concurrency and better iteration management, focusing management attention on the essential information transfer requirements of a project.

Other concepts are also presented, like the decision rules (McCARTHY et al., 2006). It consists of rules that define how the development process will work. According to the authors, they refer to the way decisions are taken during the development that affects the project congruency and performance. According to ENGWALL et al. (2005), in complement to the models, the way people conceive the tasks need to be considered. SÖDERLUND (2002) defends the use of project management mechanisms as synchronising devices, such as: time, knowledge and global arenas, respectively referring to the effects and roles of goals and milestones, the understanding of the interrelationships between different parts of a system, and interactive places for problem solving.

In doing so, the concepts presented here should be considered, once they affect the way models are developed and applied and the way that the development process works (McCARTHY et al., 2006). SHERMAN et al. (2005) state that uncertainty reduction will be facilitated by higher levels of integration across functions and the use of modes of integration that have higher potential for information processing.

4. Proposed conceptual model

4.1. Dimensions of the development process

A classification of the dimensions of the product development process is proposed based on the literature review. This classification stems from the works of KRISHNAN & ULRICH (2001) and CHENG (2000). Therefore, instead of considering an approach uniquely based on the decisions, the nature of the topics that compose each dimension is considered. The resulting classification contains six dimensions, the ones that are predominant in the literature, plus the ones that resulted from the classification based on the nature of the elements. The proposed dimensions are: strategic, organizational, technical, planning, control and operational.

The strategic dimension, according to CHENG (2001), represents an attempt to articulate the market needs, the technological possibilities and the company competencies, in a way that allows the business to perpetuate. MCCARTHY et al. (2006) affirm that the decisions in this dimension relates to market and product strategies and portfolio

management. Some decisions that can be cited as being strategic are: what is the timing of product development projects? What assets will be shared across which products? (KRISHNAN & ULRICH, 2001).

The organizational dimension consists of topics related to the social systems and the environment in which the product development activities are hold (KRISHNAN & ULRICH, 2001). A particular aspect of the classification herein proposed is the inclusion of product development models in this dimension, considering that they represent the structure the product will be developed through. This characterises it primarily as an organizational element, since this dimension contains not only the elements of a unique project, but also what refer to the whole company. Other topics like competence and technology development policies were included in this dimension as well as the integration along the supply-chain.

Another dimension that distinguishes this classification from the ones in the literature is the technical dimension. This dimension includes the product development methods and tools. According to ROZENFELD et al. (2006), they are means that exist to support the product development activities. These tools can be fit into any area of the classification proposed by PALACIOS & GONZÁLEZ (2002), which are: project techniques, organizational techniques, manufacturing techniques, information technologies and supply-chain. Some of theses tools are shown in Table 1.

Planning and control dimensions are in the context of project management. The classification herein proposed, based on the differentiated nature of its elements, divided the project management techniques in two other sub-dimensions: planning and control. The items presented in Table 1 were based on the structure of PMI (2004).

Finally, the operational dimension does not present specific topics, but consist of the project execution itself. It is about the application of the strategic definitions, in a defined organizational structure, in accordance with project plans, making use of specifics methods and tools.

4.2. Decisions and integration levels

The decision levels proposed in this article are based on the two categories division proposed by KRISHNAN & ULRICH (2001). However, they are distinguished in some aspects. Their classification is based on the decision perspective, that considers **what** is decided in the development process, instead of considering the way the development happens (i.e. **how**). In this sense, the decisions were organized in two categories, as follows: the decision in the context of a single project and the decisions in setting up a development project.

The present work uses both **how** the product is developed as **what** is decided. Therefore, it is proposed two levels of integration in the product development process. The first level refers to **how** the product is developed and was herein called the structural level. At this level, the decisions are directed to setting up the organizational context, according to KRISHNAN & ULRICH (2001), and they refer to corporative patterns. Thus, the integration at the structural level corresponds to the definition and the alignment at the company concerning the standards to be used during the development project.

The second level refers to the application of the organizational standards in a specific project. Therefore, this level contains both the decisions in a single project, as the planning and execution of the development project. The integration at the operational level corresponds to the application of the organizational patterns in the project being developed.

In this sense, the development process could be represented, in a macro view, by six dimensions and should be integrated in two levels. At a higher level, there would be an integration in the organizational context. Product development would then occur through the integration in the operational level, where the standards would be applied according to the project particularities. The development of the product would be the result of the application of the elements that compose the five dimensions (strategic,

Table 1. Product development dimensions and topics.

Strategic	Organizational	Technical	Planning	Control	Operational
Portfolio management Market intelligence Platform renewal Capacity dimensioning Budgeting	Organizational structures New product development models Competence development policies Technological development Supply-chain integration	FMEA QFD DFMA CAD CAPP CAE PDM Robust Design Modular Design, etc.	Scope definition Resources and cost planning Activity definition and duration estimating Activity sequencing and schedule development Risk identification and analysis, etc.	Scope verification Cost control Schedule control Quality control Project team management Risk monitoring and control, etc.	Development execution: application of the strategic definitions, in a defined organizational structure, in accordance with project plans, making use of specifics methods and tools.

organizational, technical, planning and control) at the operational dimension that characterises the operational integration. Figure 1 illustrates the dimensions and the integration levels proposed.

4.3. The elements and the dynamics of the product development process

Once the product development takes place at the operational dimension, the understanding of how it really occurs is of great importance (CLARK & FUJIMOTO, 1991). Therefore, it is necessary to consider the information exchange and issues associated to reworks during the development (CLARK & FUJIMOTO, 1991), the changes (BAILETTI et al., 1998), the overlaps (KRISHNAN & ULRICH, 2001), among other issues. The current analysis did not consider solely approaches or methods that deal only with subjects associated to coordination or the dynamics of the product development process. It aims at identifying and analyzing the elements that compose the operational dimension and explain the dynamics of the development project by using the concepts found in the literature review.

Initially, it was identified three basic elements that compose this dimension. Two of them were based on the elements that compose the coordination structure proposed by BAILETTI et al. (1998): the social network and the shared objects network. The third element uses the concepts of the interdependence modelling from CROWSTON (1997) that considers the interdependence between tasks and resources.

The present work proposes that the operational dimensional is composed by the following elements: a social network, a task network and other shared objects. The social network comprises the people or groups that participate in the development. The task network includes the activities necessary to develop the product. Now, the shared objects represent the information that are created and transformed during the project such as customer requirements, product specifications, design of components (BAILETTI et al., 1998), and so on. In this way, product development occurs through the integration of these three elements: the social network uses the shared object to execute the tasks and doing so, it will generate new shared objects or transform the previous ones. Considering the task of concept development, for example, the social network would use: **customer requirements** (shared objects) to **develop the product concept** (task). So, the generated concept (shared object) is used by the social network to **develop the product specifications** (tasks), for example.

A fourth element that can be included in the previous representation would be the flow of information within the project. It can be considered as a mean through which the process occurs. Figure 2 shows the interaction between these elements.

However, considering that the product development involves a large number of interdependencies between individuals and groups in an environment of highly uncertain tasks (BAILETTI et al., 1998) and overlaps (KRISHNAN & ULRICH, 2001), some properties of the interaction between the elements need to be identified and understood. Some of these properties are shown next.

The first property to be considered is the **property of information.** KRISHNAN & ULRICH (2001) affirm that an organization manages uncertainty through information processing and that a careful overlap management requires

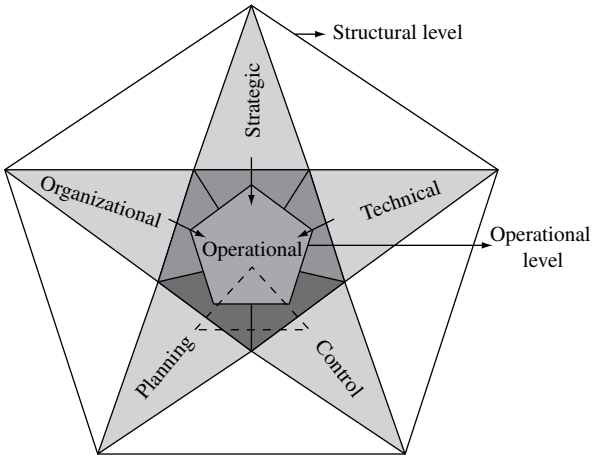

Figure 1. Dimensions and integration levels of the product development process.

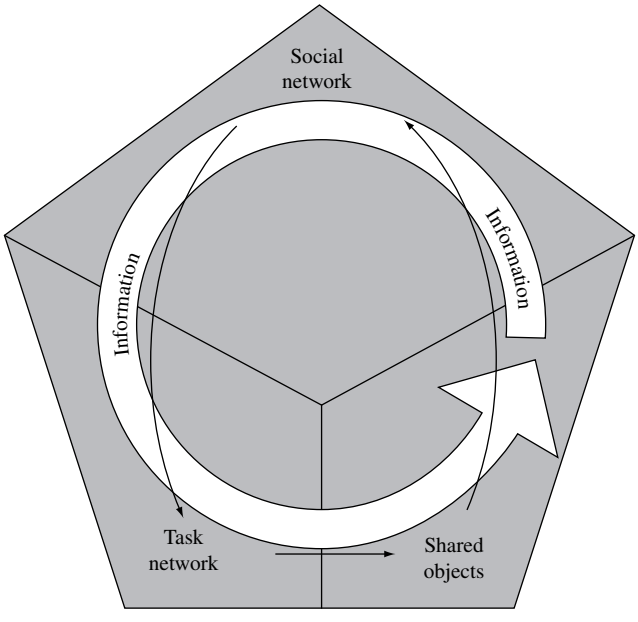

Figure 2. Interactions between the elements of the operational dimension.

a detailed representation of information exchange between individual tasks and a deep understanding of the properties of information. As mentioned earlier, these elements are synthesised and represented by the term **property of information.**

In addition the characteristics of concurrency and the iteration of the development process, it is important to identify the interdependencies between these elements. Two types of interdependencies are proposed: the responsibility interdependencies (BAILETTI et al., 1998; KRISHNAN & ULRICH, 2001) and the information interdependencies between tasks (DENKER et al., 2001). The responsibility interdependence is when individuals or groups of the social network perform interdependent activities that will affect the same shared object. The information interdependence between tasks is about how the necessary information to do the project tasks interrelates.

It is also important to consider the cognitive aspects related to the way people conceive the tasks and the implicit patterns in the decision making during the product development process. In this sense, another property to be added to the product development process would be the **decision rules** (McCARTHY et al., 2006) that refer to the way the decisions are taken during the development.

These properties are inherent to the product development process. Therefore, coordination models and approaches should consider them to ensure that collaborative actions of people working in the project are coordinated to achieve the expected result effectively (KLEIN, 1995).

Figure 3 shows the elements, the properties and the dynamics of the operational dimension. Figure 4 presents the representation of the development process with its dimensions, elements, properties and its dynamics.

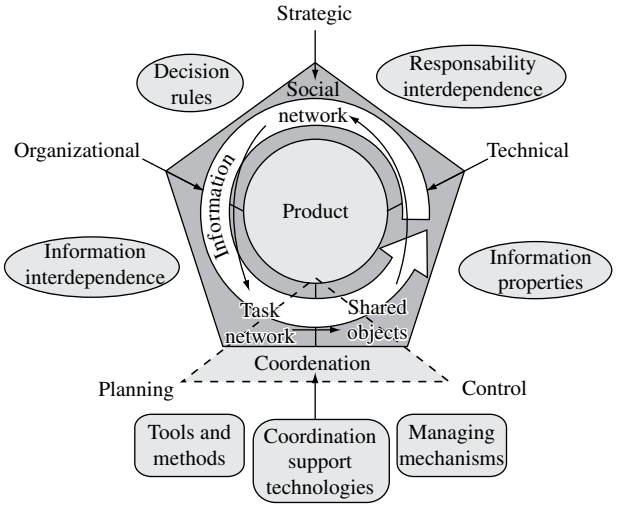

Figure 3. Elements, properties and the dynamics of the operational dimension.

5. Summary and discussion

The article presented a representation of the NPD process based on the nature of its dimensions and on the elements that compose this process. Two integration levels in the project were presented: the structural level that establishes a framework of how the products shall be developed, and the operational level, i.e. the application of the organizational standards of a specific development project.

This work tries to combine some approaches; the representation here presented does not exclude other classifications, such as the ones proposed by KRISHNAN & ULRICH (2001) and CHENG (2000). It tries to provide a clear and simple vision of how the development occurs by analyzing it from the perspective of the interaction between its elements at the operational dimension and the application of the topics of the other five dimensions (strategic, organizational, technical, planning and control) in the operational dimension that is present through the operational integration. Moreover, it suggests some properties related to these elements that influence the development process.

The understanding of the inherent properties of the development process, like the information properties, the existent interdependencies between the elements, and the decision rules that define how the development will function, also seem to be of great importance in setting up an efficient coordination mechanisms. The present study

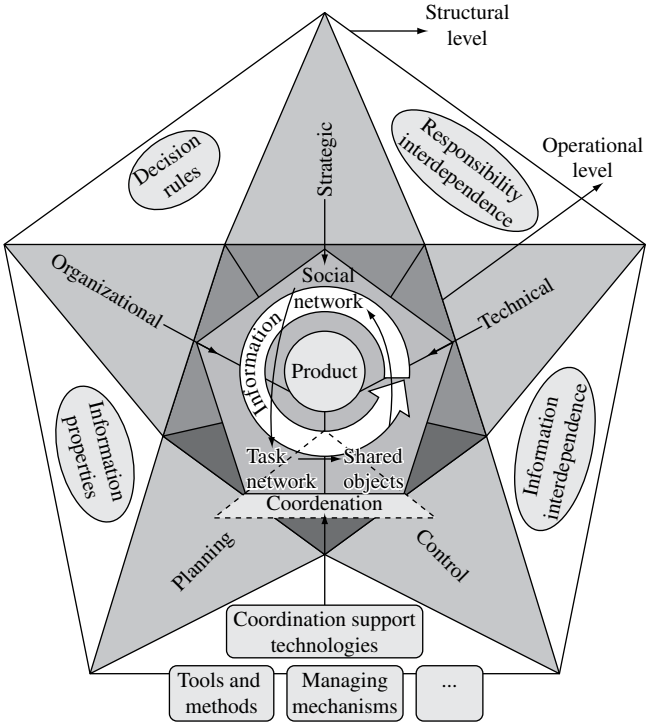

Figure 4. Representation of the conceptual model of the product development process.

does not intent to do a final analysis of how the development really occurs, neither to take a deeper look at the techniques and methods applied to the product development process. Its purpose is to provide a representation that can be used as the basis of a deeper understanding of the dynamics of product development process.

6. Concluding remarks

Since this study is part of an on-going research and it is not fully completed, conclusions should be taken with caution. Nevertheless, some concluding points can be raised. Firstly, it has been identified in the literature that, apparently, there is no conceptual model that represents all dimensions and interactions in the new product development process. Secondly, the theoretical model shown in this article meets the needs of a more adequate representation that describes the dynamics of the development process pointed out by some authors earlier cited. The conceptual model integrates different perspectives of new product development process, considering the nature of the elements as the basis for its elaboration. Additionally, it includes essential elements and properties that will serve to the development of new conceptual models. Finally, even as a preliminary study, the conceptual model here proposed tries to contribute to the understanding of the dynamics of the product development process, given the separation of the operational dimension from the other five that constitute the structure of the development project. This gives a notion that, although the methods and techniques that compose each dimension are very well understood, the conjoined application of them in a development project needs to be further detailed and studied.

In this sense, future studies shall be developed considering the points here addressed and a detailed analysis of the conjoined application of the topics that compose each dimension in the operation dimension as this seems to be relevant. In addition, an analysis of how the integration of all these elements occurs, together with methods to optimize would contribute to the understanding of such a complex process as new product development.

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