PRODUCT DEVELOPMENT PROCESS FORMALIZATION BASED ON INFORMATION/ACTIVITIVY MODELING WITHIN A REFERENCE MODEL

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Abstract. The intense competition in global market along with constant changes in customers demands have forced companies to re-think some of their business processes in order to survive and stay competitive. Product development is one of the key business processes for any competitive and global company. Its organization and formalization can provide for companies reduction in time and costs for the final product development and time-to-market. Having the product development process (PDP) defined within a formal model, by itself, can not assure total competitive advantage for companies, but the lack of it is for sure disadvantageous. For this reason, the correct definition and management of product development process can be crucial for companies. This process encompasses understanding the costumer's needs, defining the design concept, manufacturing the product, selling and finally discarding the product. Many studies and methodologies, academic and industrial, have been proposed in this area. However each company has its own PDP that fits into its technical and cultural needs. Eventually this process is not formal or even recognized, but it exists. For this reason, companies should accept the PDP as a strategic business process, which must be learned, understood, well structured and, and in constant maturity. This maturity process can be realized not only internally, learning from its own processes, but also using some external reference models for PDP for evaluations. Theses reference models allow a more systematic comparison of the company's PDP, identifying activities that can be improved and optimized. This paper presents a study related to the analysis, modeling and formalization of a product development process, by identifying its main activities and comparing with an external reference model for PDP. IDEF0 notation was used for modeling the PDP. The main goal of this work is re-evaluate the company's PDP, aiming shorter product development cycles, by reducing inappropriate and excessive workflows, efforts and information. The work presented on this paper was realized in a metal-mechanic company, which produces liquid filling and packing machine lines applied to different segments, such as pharmaceutical, hygienic and cleaning, chemical, food, cosmetics and others. These machine lines are considered as one-of-kind products, as they are specifically tailored for each customer.

Keywords: Product development process; activity modelling; reference model.

1. INTRODUCTION

The intense competition in global market along with constant changes in customers demands have forced companies to re-think some of their business processes in order to survive and stay competitive. Product development is one of the key business processes for any competitive and global company. Its organization and formalization can provide for companies reduction in time and costs for the final product development and time-to-market. Having the product development process (PDP) defined within a formal model, by itself, can not assure total competitive advantage for companies, but the lack of it is for sure disadvantageous. For this reason, the correct definition and management of product development process can be crucial for companies. This process encompasses understanding the costumer's needs, defining the design concept, manufacturing the product, selling and finally discarding the product. Many studies and methodologies, academic and industrial, have been proposed in this area. However each company has its own PDP that fits into its technical and cultural needs. Eventually this process is not formal or even recognized, but it exists.

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This paper presents a study related to the analysis, modeling and formalization of a product development process, by identifying its main activities and comparing with an external reference model for PDP. The main goal of this work is re-evaluate the company's PDP, aiming shorter product development cycles, by reducing inappropriate and excessive workflows, efforts and information. The work presented on this paper was realized in a metal-mechanic company, which produces liquid filling and packing machine lines applied to different segments, such as pharmaceutical, hygienic and cleaning, chemical, food, cosmetics and others. These machine lines are considered as one-of-kind products, as they are specifically tailored for each customer. The next sections present a brief survey about PDP process and process

modeling, followed by a product development process modeling and its comparison with an external reference model of PDP. Finally a case study and the conclusions are presented.

2. PRODUCT DEVELOPMENT PROCESS - PDP

2.1. Definitions and generallity

Putting a new product in the market is not an easy task for most companies, being usually a result of a long time process involving several activities and functional sectors of the company. However, this is necessary to ensure the business of the company and consequently its survival in the future. There are several factors that push the product development process, and they usually are associated with the dynamic relationships of the others company business process and environment (Leite et al. 2007).

The PDP (*Product Development Process*), when compared to other company business process, has a wide range of specificity (Moreira, 2005; Dixon, 1995), such as high level of uncertainties and risks in the beginning of the process, managing and generating of a large amount of information and knowledge, different sources of information, and several requirements and restrictions considering all phases of the product lifecycle. All these characteristics make this process very complex and unique, demanding appropriate management models and practices (Dixon, 1995).

Usually in the initial phases of the PDP are defined the main specifications and design solutions of a product, where are defined materials, technology, manufacturing processes, etc.. Clark and Fujimoto (1991) state that about 85% of the product cost are defined from choices made during the initial phases of the product development process, i.e. at the design phase, where the uncertainties are very high. These choices can be both about the product itself, and about the manufacturing processes. For this reason, it is important that uncertainties be minimized, by ensuring quality information and a rigid control of the process phases. The first step for that is having a well defined, structured and formalized PDP.

2.2. PDP Reference Models

Some authors such as Norton (2004), Pahl *et al* (2005) e Baxter (2000) define, or classify, some phases of the PDP in order to better understand the characteristics of each one. This allows that any changes made in the PDP can be focused on each phase specific. However, this classification is not same for all kind of products or companies, requiring, eventually, some adjustments.

Norton (2004) states that PDP is composed by nine main phases, which are: identifying product needs, survey, objectives definitions, tasks specification, conception, data analyses, suppliers and/or components selection, detailed design, prototyping and testing, and manufacturing.

Pahl *et al* (2005) say that product development process is based on interactions among four phases: study and analysis of product, conception, preliminary design and detailed design. For each phase there are different work steps that must be realized to achieve the establish goals.

Baxter (2000) states also that the PDP must follow different phases from the ideas to test in the market to the product detailed design, manufacturing and prototyping. These phases do not define a straight forward process, but each phase can be repeated as many times is necessary, depending on the number of decision made during this process.

Rozenfeld *et al* (2006) presents a Unified Model of PDP, where different stages, phases, and activities are formalized. This model, which gathers concepts, structures, tools, methodologies and other aspects, from different literature, provides a generic basis for the PDP. This Model could be used as a external reference model for companies that evaluate or compare their own PDP.

Ulrich e Eppinger (1995) address some main phases to the PDP, which are identifying costumer needs, concept development, product architecture, detailed design, testing, and product production.

In addition to the main phases, the PDP must also consider the level of product innovation or novelty. For example, Ulrich and Eppinger (2004) classify the PDP in four different types: a) platforms of new products; b) platforms of existing products; c) improvements of existing products; e d) new products. This work presented in this paper is mainly related to the b) e c) types.

2.3. Business Process Modelling

Garvin (1998) states process as a collection of tasks and activities that togeger transform inputs in outputs. Cruz (2003) says that process is a group of activities that have as objective transform input, adding value by procedures, to artifacts and services, which must attend and be deliver to the customer.

Processes in a company can be internal (begin and finish inside the company) and external (when goes beyond the company's boundary). Gonçalves (2000) defines three categories of processes:

    a)   Business process (or customer's process): connected to the different company's functional areas, resulting in a product or service to the final customer. The PDP process can be defined as this kind of process;

b) Organizational process: centered in the organization and are not perceived by the external customer. They are essential for supporting the business processes.;

c) Management process: focused on the managers and their relationships.

In order to analyze and model a process is necessary to have some information about it, such as process goal, physical and logic inputs and outputs, controllers, rules, etc.. It is also necessary the use of a defined notation that provides a clear process representation, in a common and understandable language for all involved. Two aspects must be stressed when modeling processes: functions (or activities) and the relationships between these functions. Lin et al. (2002) present a comparison among different notation to business process modeling, classifying in four approaches: activities oriented, object oriented, role oriented, and speech-act oriented.

As mentioned before, the PDP, as a part of business process, is composed by a sequence of phases/activities. However, the PDP is also a decision taking process, what creates a strong dependence among its activities. Therefore, to a company that desires to evaluate its PDP is necessary to comprehend each one of functions associated to this process, identifying main inputs, outputs, controls and actors.

3. COMPARING ENTERPRISE PDP TO A REFERENCE MODEL

To model the activities and information of a PDP, this work has defined the IDEF0 notation (IDEF, 2007; CHENG-LEON, 1999), which is a well structured notation to model activities and information. The IDEF0 (Integrated Definition Methods) allows to build different visions of the PDP, in different levels of abstractions. Thus, the models build can represent from a macro vision of the process to a detailed and specific vision of the process using the very same notation. Theses models will provide an understanding about the working and integration of different activities realized by the different sectors of the company. Figure 1 shows an example of the IDEF0 notation, where in the box appear the activity/function and the arrows define the ICOM's (Input, Control, Output and Mechanism).
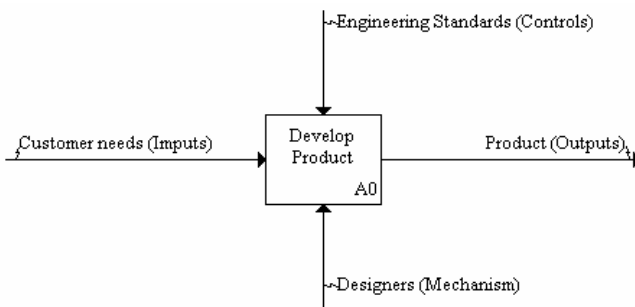

Figure 1. Example of a IDEF0 Diagram

Usually, the first model generated by the IDEF0 notation represents the process "as is". After having the comprehension of the process, the notation can be used to represent the process "as should be". However, in order to better understand the PDP "as should be" an external reference model for PDP shall be used. This is the methodology used in this work (Figure 2).
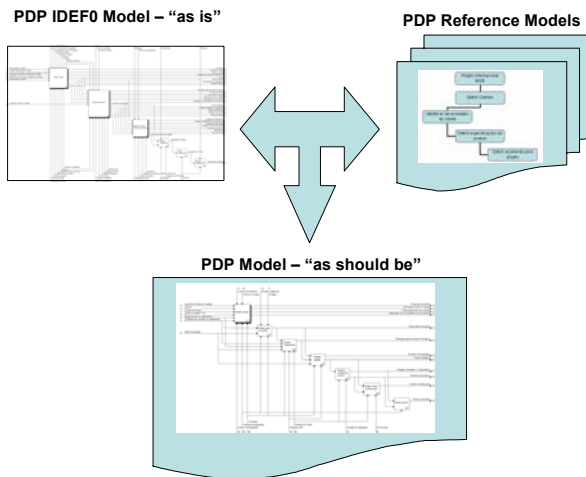

Figure 2. Methodology using IDEF0 and PDP reference models

The comparison of a specific external PDP reference model with the IDEF0 "as is" model allows an evaluation of the company's actual PDP identifying activities, information and actors that could be included, excluded or changed to improve this process efficiency. The main issue about building the IDEF0 model is to know the PDP activities in details, providing a scenario for analyzing and making further changes in the PDP process.

4. PDP ANALYSIS – STUDY CASE

4.1. PDP overview

As mentioned in the introduction of this paper, this research was realized in a metal-mechanic company, called IMSB, which produces liquid filling and packing machine lines. Its products, i.e. machine lines, are made on specific demand (one-of-kind), where the interaction between commercial and engineering area is very intense and crucial to the product development.

The current companies PDP is not formalized and structured resulting on delays and constant changes in the product specification and design, and manufacture workflow. The PDP is focused main on the company's functional structure, e.g. selling, design, manufacture, purchase sectors.

Figure 3 depicts the IDEF0 diagram for the current PDP in the company. It shows the following phases, or activities: make selling – A1 (*Efetuar venda*), develop design – A2 (*Desenvolver projeto*), plan production and manufacture components – A3 (*Planejar a produção e fabricar componentes*), assembly product – A4 (*Montar equipamento*), test product – A5 (*Testar equipamento*) and dispatch final product – A6 (*Expedir equipamento*). The first activity is under Commercial Direction responsibility, while the others activities are under Technical Direction responsibility. To show the ideas developed, the work presented in this paper has explored two specific activities: make selling (*Efetuar venda*), develop design (*Desenvolver projeto*).
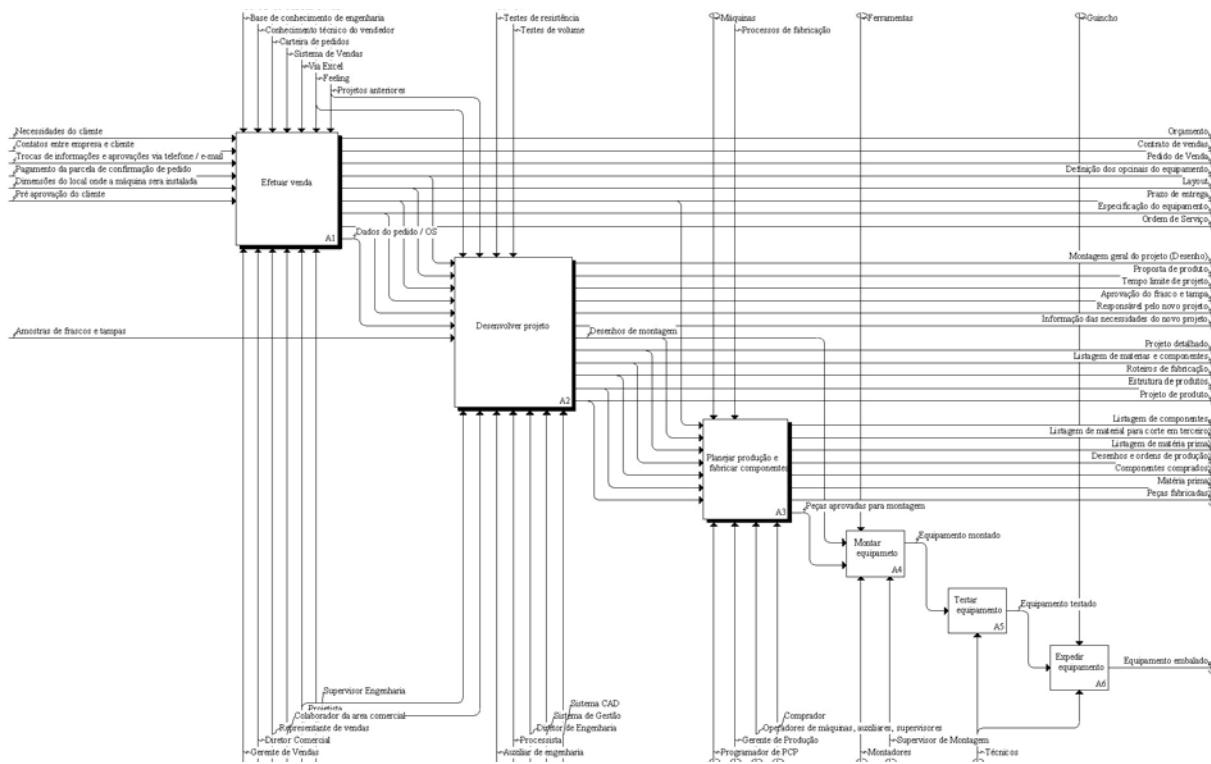

Figure 3. IDEF0 for current Company´s PDP main phases

For building these two IDEF0 models there was no major concern to the formal terminology used by the literature. The focus was identifying the main activities and information involved in the PDP business process, using familiar terms to the company.

Interviews were realized with staffs (commercial and technical) to obtain the information about the PDP. The interview process was informal, observing workstations main tasks, existing procedures, and the reason for each activity. During the interviews the observer did not express, anytime, his opinion about the process observed.

4.2. Making selling (efetuar vendas) – Activity

In a first overview, the sector of selling has some problems related to the information flow, poor defined process, missing product specifications, and seasonal sells. This results in incompletes information in the beginning of the PDP, what requires constant intervention of the designers and/or design and manufacturing re-work.

The activity Make Selling (*Efetuar venda*) is divided in five sub-activities (Figure 4), known as: contact costumer – A11 (*contatar clientes*), define product specification – A12 (*definir especificação do equipamento*), elaborate selling documentation – A13 (*elaborar documentação de vendas*), make negotiation – A14 (*efetuar negociação*), Generate selling and service order – A15 (*gerar pedido de venda e ordem de serviço*).

In the first sub-activity, contact costumer (A11), a costumer is contacted by a commercial representative, e.g. vendor, commercial manager or eventually the commercial director. If there is a possibility of negotiation, the costumer needs are captured (A12) and than transformed in a set of specification. In this phase (Figure 5), there is a feasibility analysis of the project (A121), where the specifications are defined (A122) and approved by the commercial a technical areas (A123).

In the activities sequence (Figure 4), the selling documentation is created (A13). This documentation is composed by product layout, budged and contractual schedules. Based on these pieces of information the final negotiation is realized (A14) and once approved, the selling order and service order are generated (A15).
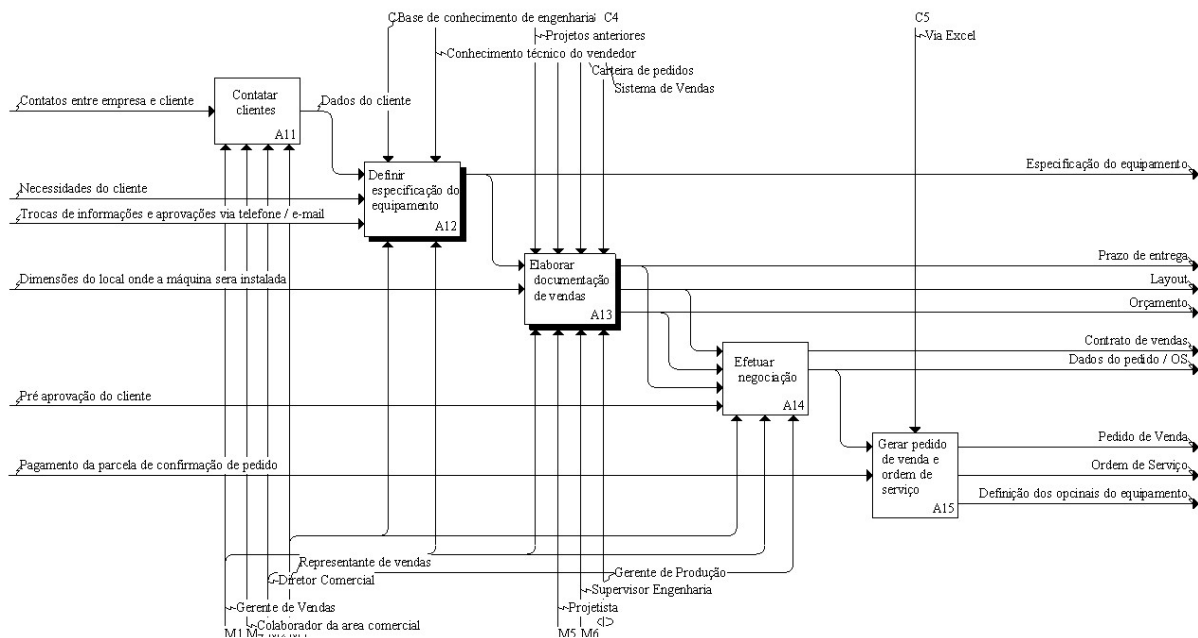
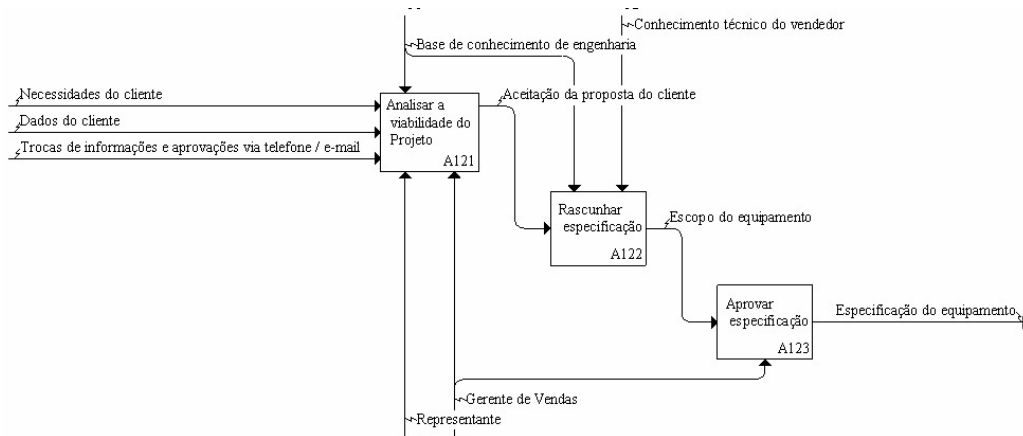Figure 4. Decomposition of "Make selling" activity

Figure 5. Phase "define product specification" – A12

4.2. Develop design process (*Desenvolver projeto*) – Activity

Figure 6 depicts the decomposition of develop design activity. The following sub-activities are defined: analyse design – A21 (*analisar projeto*), define project schedules – A22 (*definir prazo do projeto*), design product – A23 (*projetar equipamento*), detail design – A24 (*detalhar projeto*), define product structure – A25 (*cadastrar estrutura do produto*), define manufacturing plans – A26 (*definir roteiros de fabricação*) and revise design – A27 (*revisar projeto*).

The first sub-activity, analyze design (A21), is mainly related to the conceptual design phase. Based on information provided by the commercial area, specifications and samples send by the customer the first concept of the final product is design.

In the second sub-activity, a schedule and final date are defined to delivering the product. This is done based on the previous experiences of the company. This is usually made by the engineering supervisor and there is not formal process for this.
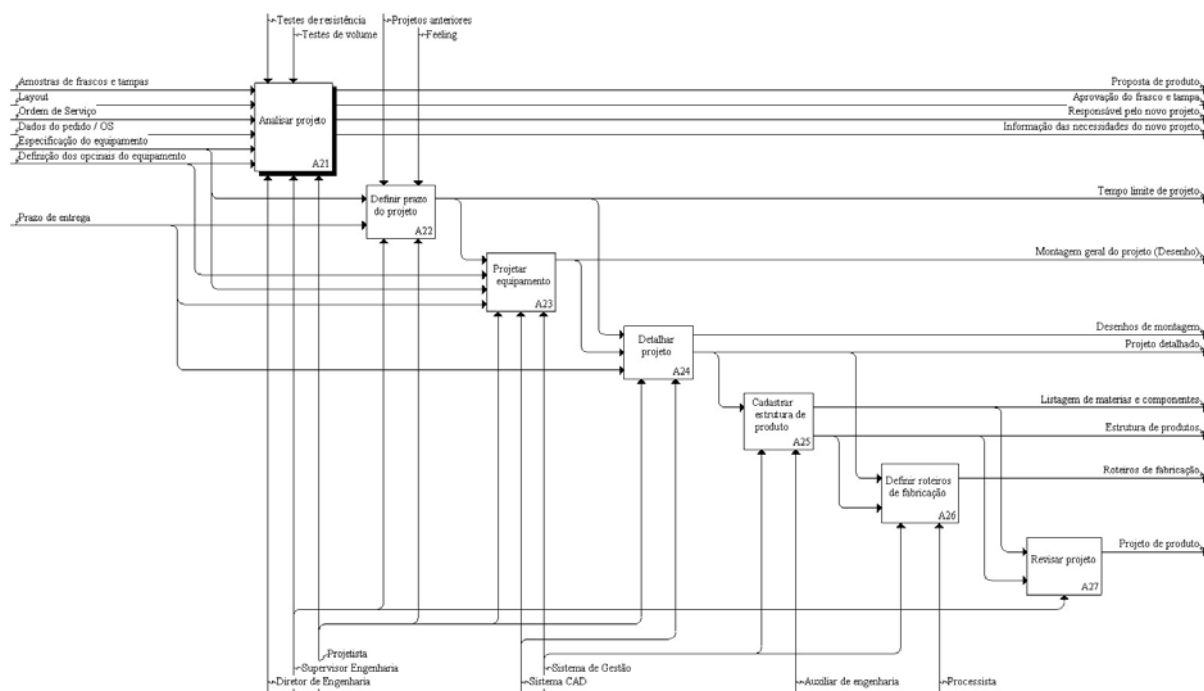

Figure 6. Decomposition of Develop Design process

The sub-activity design product – A23 is associated to the product architecture definition, where the main product systems, or modules, are defined. In the following activity, detail design – A24, the product structures are defined along with the product design details. After that, the manufacturing plans are defined (A26), and finally the product design is revised (A27).

5. PDP ANALYSIS BASED ON A REFERENCE MODEL

The IDEF0 model provided a well detailed vision about all functions involved in the PDP studied. However, it does not define or classify the activities into formal processes and sub-processes related to a PDP Reference Model. This work has chosen as a reference model, the PDP Unified Model, presented by Rozenfeld et al. (2006). It was chosen mainly because it shows each PDP phase in terms of activities, which makes easier the proposed comparison. Thus, the activities modeled in the IDEF0 notation are associated to the PDP Unified Model from the literature.

Figure 7 shows the association between the activities defined in the reference model phase called ***identifying costumer needs (Projeto Informacional)*** and the activities modeled in the IDEF0 (for example A11, A121, A122). In the previous PDP process these activities were performed isolated (different functional sectors). The analysis of the PDP phase allowed defining it as a key-process, within the PDP, i.e. the focus has changed from sectors to the process.

In a similar way, the analysis was made to the Conceptual Design and Detailed design phases. For the Conceptual Design phase, an initial meeting is realized to discuss the product alternatives concepts to the product. In this phase, based on the product specifications, a first product architecture must be created, defining potential and alternative product systems, sub-systems and components solutions. Finally, at this phase, choices are made to the final solution (Figure 8).
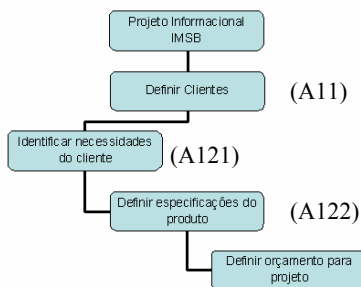
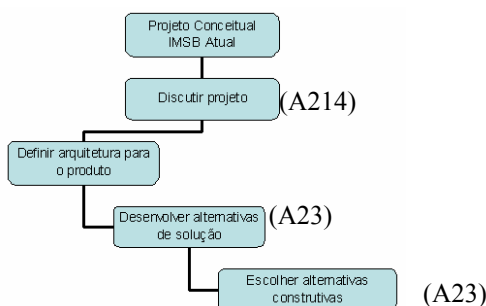Figure 7. Proposed activities for the "identifying costumer needs" (*Projeto Informacional*)

Figure 8. Proposed activities for the "Conceptual Design"

The Detailed Design phase begins with the creation and detailing of the product systems, sub-systems and components (SSC) (Figure 9). After that, it splits in two activities: optimize product and process, and develop suppliers. The creation of product SSC's allows the definition of the product final structure, which is the base to define the manufacturing plans, purchase, assembly, etc..

To test the ideas developed in this research, an actual company's product was chosen in order to verify the changes in the PDP. The product is part of a beverage packing machine, more specifically a capper (sealer) unit, as shown in Figure 10. This equipment is composed by different numbered parts (1 to 16) as also shown in the figure.

One of the changes resulted from the analysis and improvements made in the company's PDP, was the formal definition of main product architecture. This was not done before. Thus, four main groups were defined for the product architecture, called G1 to G4. The group G1 contains the machine base (1). The G2 contains the items 2 and 10. The G3 contains items 3 to 9. Finally, G4 contains items 11 to 16. The result of the architecture definition was formalized by activities detailing and sequencing (Figure11), which can provide a better control of design and manufacturing activities.
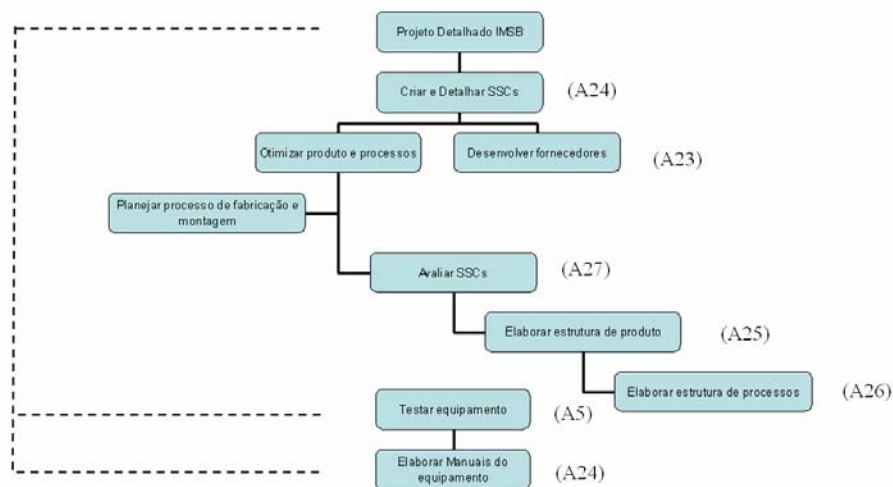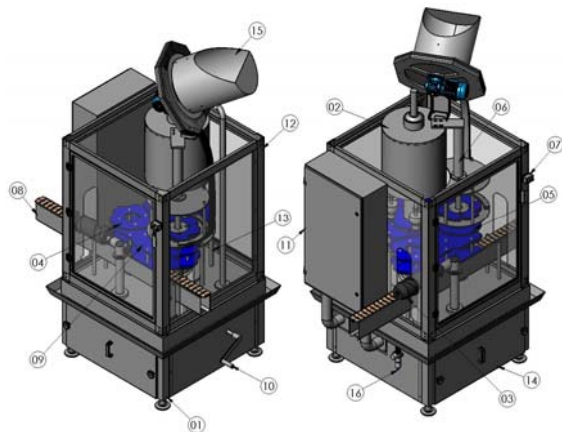

Figure 9. Proposed activities to "Detailed Design"

Íten	Descrição		Íten	Descrição
01	Conj. Base		09	Conj. Mesa dos Frascos
02	Conj. Rosqueador		10	Conj. Regulagem de Altura do Rosqueador
03	Conj. Sem Fim		11	Conj. Quadro de Comando
04	Conj. Estrela de Entrada		12	Conj. Cabine
05	Conj. Estrela de Saída		13	Conj. Guia externo do Rosqueador
06	Conj. Pick and Place		14	Conj. Fechamento
07	Conj. Posto Móvel		15	Conj. Alimentador de Tampas
08	Conj. Esteira da Máquina		16	Conj. Lubrefil

Figure 10 Capper machine TSB25.06 [www.imsb.com.br, 2008]

6. CONCLUSIONS

The work presented in this paper has shown how to define a company formal PDP, based on activities and information modeling of a business process (PDP), and making use of an external PDP reference model.

The generated IDEF0 diagrams allow understanding the product development process main activities and information, their relationships, and the interactions among different functional sectors of the company. The notation can be considered easy to use and efficient for the PDP modeling. However, it is not focused on the process flow. Additional work is being realized using other notations, such as BPMN (Business process management notation).

The main PDP phases (external reference model), identifying costumer needs, conceptual design and detailed design, have shown clear and well defined. However, it is necessary that these phases are well understood by whom is doing the comparison process with the IDEF0 model.

The IDEF0 models have provided a better understanding of the current company PDP, and the proposed PDP has brought improvements in terms of standard activities for PDP planning and execution, and better workflow between company's function sectors.

Further work is needed testing the ideas in other kinds of companies, other kinds of products and using different PDP reference models. Also, an extension of this work could be made for other company's business processes, such as manufacturing, purchasing, etc..
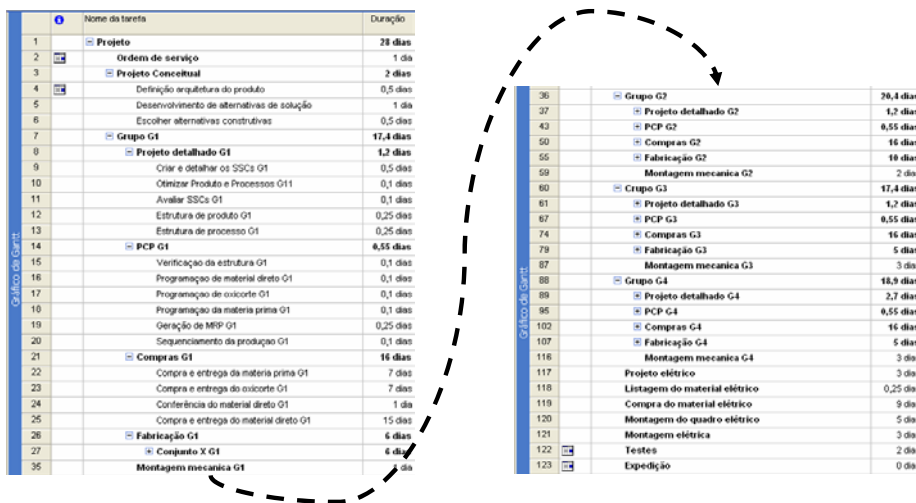

Figure 11. Example of activities sequencing for the proposed PDP

7. ACKNOWLEDGEMENTS

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