Evaluation of maturity levels in the management of product development: case studies in the capital goods industry

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Abstract: In recent approaches to the management of product development process (PDP), maturity levels have attracted the attention of practitioners and researchers. The CMMI model contributes to evaluate the maturity levels and improvement of the product development process management. This paper, based on CMMI model, analyzes the practices adopted in two companies of the capital goods industry, which develop and manufacture equipment upon request. It was observed that on account of market conditioning factors and different practices adapted to PDP management, these companies are at different maturity levels. One company is at the initial level of maturity while the other at the most advanced one. It was also noted that the application of CMMI model can provide improvement to PDP management, as well as present guidelines to achieve higher maturity levels, adequate to companies' needs.

Keywords: product development process (PDP), maturity model, capital goods industry, product development management.

1. Introduction

Technological transformations and stronger competition have forced companies, both locally and mainly globally, to faster develop new and more complex products, with higher quality and at lower cost. The efficient development of new products is recognized as allowing new opportunities to companies, however the development and launch risks should not be neglected (ERNST, 2002; KAHN; BARCZAK; MOSS, 2006).

The importance of academic researches on Product Development Process (PDP) is due to the evidences of those opportunities and risks, since besides pointing at good management practices which will minimize those risks, may also contribute to improve the steering of such process, thus optimizing the company's performance.

The main research lines on this subject aim at identifying the management practices which increase the success probability of the product to be developed (COOPER; EDGETT; KLEINSCHMIDT, 1999; KAHN; BARCZAK; MOSS, 2006; ROZENFELD et al., 2006). Those research lines also study PDP specific aspects, such as new products development projects, the adoption of concurrent engineering principles, stage-gates, fast prototyping, and quality function deployment, amongst others (CAFFYN, 1998; COOPER, 2007; CHENG; MELLO FILHO, 2007).

More recently, subjects like lean product development, design for six sigma, maturity models and products life cycle management, have arisen the attention of researchers and practitioners (CREVELING; SLUTSKY; ANTIS, 2003; DOOLEY; SUBRA; ANDERSON, 2002; MOULTRIE; CLARKSON; PROBERT, 2007).

Specifically, the PDP management maturity model has called attention, since the adoption of maturity levels allows to diagnose the current PDP performance of a given company, as well as what should be done regarding management to improve that process and its performance (FRASER; MOULTRIE; GREGORY, 2002; KAHN; BARCZAK; MOSS, 2006).

Concomitantly, according to Amaral, Rozenfeld and Araújo (2007), the PDP management maturity level indicates how much a company applies of the best existing and known practices associated to that process. Departing from that reasoning, more mature is the PDP management of the company, better is process performance, what will result in greater success probability for the developed products and, consequently, greater company's competitive capacity (DOOLEY; SUBRA; ANDERSON, 2002). Figure 1 shows that reasoning.

The study and adoption of maturity models may be considered a consolidated knowledge field specific for software development, because of the CMMI (Capability Maturity Model). The Software Engineering Institute developed such model, successfully adopted by many companies in different countries (DOOLEY; SUBRA; ANDERSON, 2002; CHRISSIS; KONRAD; SHRUM, 2003; QUINTELLA; ROCHA, 2007).

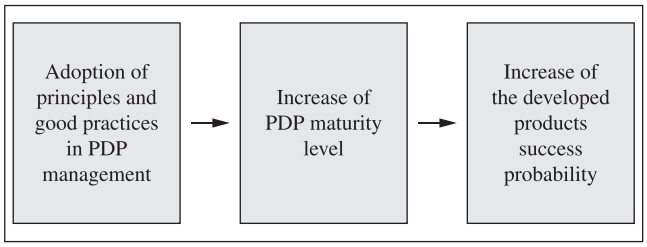

Figure 1. Relationship amongst good PDP management practices, maturity levels and success probability for developed products.

However, there is a lack of works approaching maturity levels for the development of tangible products. Thus, using the accepted CMMI's model may be useful to help companies identify maturity levels for the development of tangible products.

Considering the research subject "PDP management", it is important to observe that its practices become evident in differentiated ways, according to the industry and a given product world production. Thus, the academic research may contribute to better understand management practices and PDP critical success factors in a given industrial sector, whose characteristics and complexity are peculiar as compared to other industrial sectors.

Therefore, it is of upmost importance to study that process, focusing the peculiarity of a specific industry, which should also operate in a sector economically and technologically significant to the country. That is the case of the capital goods industry that, according to Vermulum (1995), due to its supplying machines and equipments to all industries, is basic for the industrial development of any nation. The author also considers the capital goods industry as a part of the beginning of the productive chain, capable of influencing industrial chains through a technological innovation and competitiveness culture (for example: other companies engaged in capital goods, final consumer goods and infrastructure).

Nevertheless, despite the importance of this industry for the industrial development, studies point out that the Brazilian capital goods companies have faced sensible difficulties to carry out their innovation activities as well as new products development (VERMULUM; ERBER, 2002). This is due, according to Vermulum (1995), to the companies' insufficient qualification to perform new products development activities.

Furthermore, as observed by Davies and Hobday (2005), capital goods companies have PDP management peculiarities, are normally devoted to activities involving project and delivery of products that are complex from the engineering point of view, resulting in a high project-associated risks trend.

PDP management in medium and large Brazilian companies of the capital goods industry deserves special attention. According to Resende and Anderson (1999) and Vermulum and Erber (2002), those companies normally have the conditions and resources necessary to perform systematic new products development activities, such as: facilities, machines, adequate labor, R&D investment and specific project and product skills.

Taking into account the lack of empirical PDP management knowledge in Brazil's capital goods companies, it is necessary to carry out studies to investigate the peculiarities of that process. Therefore, the main objective of this paper is to understand the PDP management maturity level and identify improvements in capital goods companies, medium and large size respectively.

The paper is organized in four topics: the theoretical review on PDP management and maturity levels; following by the research method adopted, concluding with the presentation of results and final considerations.

2. Bibliographical review

2.1. Management of product development process

Aiming at competitive product market results through the project execution, many authors recommend that companies use a management reference model. Among the models proposed by several authors, the consensus is that PDP should be represented as a set of pre defined stages carried out simultaneously (CLARK; FUJIMOTO, 1991; CLARK; WHEELWRIGHT, 1993; CLAUSING, 1994; HAYES et al., 2004; ROZENFELD et al., 2006; MOULTRIE; CLARKSON; PROBERT, 2007).

Several authors propose pre defined stages models to better manage the products development phases (CLARK; FUJIMOTO, 1991; CLARK; WHEELWRIGHT, 1993; PUGH, 1996; ROZENFELD et al., 2006). Interpretation of studies carried out by Clark and Wheelwright (1993) and Rozenfeld et al. (2006) suggests that, as a rule, product development activities are constituted by the following phases:

- Pre-Development: aims at establishing a link between the company's prioritary objectives and the portfolio of projects to be developed and the development planning of each project individually;
- Development: defines product functional structures and solutions, involving technical and technological information on requirements and specifications, including the definition of systems, sub-systems and components, which yield the product expected functions. In that stage, the product design-build-test-optimize activities take place until its validation;

- Post-Development: consists of systematic monitoring of information on product market results, production, distribution, customer relations and service. It also includes the product withdrawal from the market and assessment of the product life cycle.

Independently of the phases adopted, product development management can be viewed as a process, which means, according to Baxter (1998), to carry out all the activities aiming at meeting clients' needs, from generating the product concept to the product obsolescence. The application of the processes approach to product development activities implies, according to Jugend (2010), in a appropriate integration among the many functions of a company, specially Engineering, Research and Development (R&D) Marketing and Manufacture.

Since it is not a company routine process, but results of endeavor that can last for a significant time and involve all the functional areas of the organization, the development of new products is a complex process which demands, in order to be successful, not only technical capacity but also managerial capacity (GRIFFIN, 1997; HAYES et al., 2004).

Many focuses of studies in PDP are related with management variables to success and failure (CLARK; FUJIMOTO, 1991; CLARK; WHEELWRIGHT, 1993; CLAUSING, 1994; SOUDER; BUISSON; GARRET, 1997; KAHN; BARCZAK; MOSS, 2006). Within the variables in the literature concerning PDP management, determinant factors on the result of the new product can be emphasized, namely: innovation degree of the new product; technology sources used; characteristics of the products developed and characteristics of the target market (effective needs conversion); technical skills of the company; competence of the project leader (technical and managerial); functional integration; organization of team project; and PDP execution quality.

Within that context, it can be observed that PDP, to be successful, requires adequate management capacity (SOUDER; BUISSON; GARRET, 1997; ERNST, 2002). One of the approaches to adequate the new products development activities of a company is by applying the maturity levels concept (AMARAL; ROZENFELD; ARAÚJO, 2007; MOULTRIE; CLARKSON; PROBERT, 2007); subject that will be presented and discussed in the next topic.

2.2. Maturity levels in the management of products development

Within the management context, the application of maturity levels concept has become more intensified over the past years, because it furnishes a reference structure for the oriented improvement of a specific reality. Thus, maturity models proposal deal with activities involving quality management, software development, relationships with suppliers, new products development, innovation capacity and projects management (FRASIER et al., 2002).

According to Dooley, Subra and Anderson (2002), maturity models offer a method to improve adopted management practices, because of their descriptive character of maturity management relating practices, methods and tools at different maturity levels.

Discussions on the maturity levels concept began within the quality management environment (MOULTRIE; CLARKSON; PROBERT, 2007). Crosby (1994) noticed that a company's quality management-related activities are subjective and difficult to define and measure. Upon this consideration, the author developed and proposed a model to assess the quality management maturity, grounded on five maturity steps: uncertainty, wakening, clarification, wisdom and certainty.

Under Crosby's work influence, the application of the maturity levels concept to a company's activities became popularized in the business world by the software industry (QUINTELLA; ROCHA, 2007). SEI (Software Engineering Institute) took the initial steps, by developing and proposing a Capability Maturity Model, sponsored by the USA Department of Defense, to assess their software suppliers' development and production capacity (DOOLEY; SUBRA; ANDERSON, 2002).

Juang et al. (2004), who researched on the subject, perceived that software development processes in American companies were often unsuccessful, mostly due to the following factors: inadequate activities planning, little knowledge of development process, and lack of supporting structure involving engineers and managers to lead software development projects.

Through a partnership work in the decade of 1990, Software Engineering Institute (SEI) together with Carnegie Mellon University, developed and proposed some management practices to help companies progressively improve the softwares development process. Later on, according to Dooley, Subra and Anderson (2002) and Jiang et al. (2004), those practices formed a structure to assess this process improvement, which spread all over the world, named as Capability Maturity Model (CMMI).

By analyzing the CMMI adoption impact, Aguilar-Savén (2004), Chrissis, Konrad and Shrum (2003) and Dooley, Subra and Anderson (2001) observed that, however developed specifically for the softwares development process, it currently serves as a useful benchmarking tool for the CMMI practices adoption by any company dealing with a new product development business process. The research performed by Quintella and Rocha (2007) illustrates well that potential, since they utilized the CMMI model to measure the maturity level in PDP management within automotive OEMs in the State of Rio de Janeiro.

The CMMI is composed by 5 maturity levels. According Dooley, Subra and Anderson (2001), Chrissis, Konrad and Shrum (2003) and Aguilar-Savén (2004), each one of those levels can be defined as follows:

2.2.1. Initial

The development process has no type of pre-defined pattern; may even be chaotic. The company does not intend to standardize and understand the process systematic. The success of the development process mostly depends on individual efforts and talents and not on its systematic. Processes in that maturity level, normally produce products and services according to specifications, although often exceed budgets and delay foreseen schedules due to the instability of the development environment.

Employees are work overloaded due to problems emerging from the lack of a previously known systematic related to the development process, what prevents from repeating successes already made.

2.2.2. Managed

This maturity level indicates the process is planned and controlled due to the knowledge and experience of the individuals involved in the process. The tacit knowledge of the individuals involved in the process allows replicating efforts and actions over time.

2.2.3. Defined

The process patterns are clearly described in procedures, methods and tools, which indicate process purpose, inputs, activities, functions, performance indicators, activities analysis, and outputs. Through that detailed process standardization, the company intends to have every one involved in the development understand the development systematic.

The difference between this level and the preceding one, is just the concern with a better understanding of the development process, what allows its proactive management, that is the explicit knowledge making the search for improvements possible.

2.2.4. Quantitatively managed

The determination of quantitative criteria, to assess the development process performance, starts from the company's internal and external customers' needs. Process data collection and statistical analysis allow the performance measurement and control. In this maturity level the process is measured, analyzed and controlled starting from the quantitative data, aiming at turning the development process predictable.

The difference between this level and maturity levels 2 and 3 refers to the way to foresee the process performance. In maturity level 4, process performance is measured through quantitative methods, while in level 3, performance measurement is carried out in a qualitative way.

2.2.5. Optimized

The company tries to continuously improve the development process performance through innovations. Besides controlling, measuring and analyzing the process (levels 2, 3 and 4) this maturity level includes constant activities oriented to process improvement (continuous improvement).

Figure 2 shows how process maturity evolves as it follows the CMMI model.

In general, according to Aguilar-Savén (2004), by analyzing processes under the maturity levels perspective proposed by CMMI, its management becomes easier. According to that author, processes in levels 1 through 3 need to be understood and analyzed, since processes in levels 4 and 5 need to be monitored and controlled.

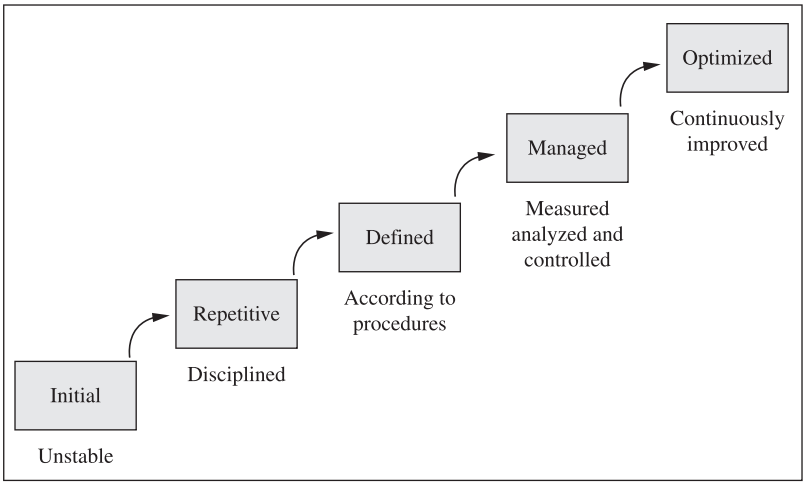

Figure 2. Maturity levels for a business process, according to the CMMI.

When analyzing maturity levels in 176 software companies, according to the model proposed by CMMI, Williams (1994 apud DOOLEY; SUBRA; ANDERSON, 2001) observed a positive correlation between higher maturity level of the software development process and performance indicators:

- Reduction of after launch software defects.
- Time to market reduction.
- Reduction of costs emerging from quality problems and final product.

Following the theoretical review on the research subject, the next topic will present the research method adopted; finally, results will be presented and discussed.

3. Research method

With the objective to understand the maturity level in PDP management, and its implications in two capital goods companies which develop tailored products, the option was to utilize the approach of the qualitative exploratory research. Besides the difficult measurement variables, it was necessary to understand people's opinion about the variables, what, according to Bryman's (2006) recommendations, made the researcher presence in field necessary.

The exploratory character is grounded on the few existing publications which relate maturity levels in PDP management within companies developing tailored goods. Thus, this work mainly intends to identify initial concepts on this subject.

By following Yin's (2005) orientation and targeting the main objective of this paper, the case study method has been chosen as the most adequate for this research program, because of the specific type of questions proposed, the extent to which effective contemporary events are controlled and how the research sheds light to these events.

Beyond that, according to Yin, the case study allows an intense analysis of a relatively small number of situations and, sometimes the cases number reduces to just one due to the wide phenomenon understanding.

Two companies were chosen by applying the intentional sampling concept. Preliminary contacts with professionals confirmed they had the skills necessary to classify a company of the capital goods sector as medium or large size; it was also observed those companies systematically develop and manufacture tailored goods for different industrial customers.

The field research utilized semi-structured interviews, what helped obtain an large view of the variables studied. Besides visiting both companies, interviews in company A included employees of the quality, engineering and manufacture areas; interviews in company B included one engineer from the project area, one engineer from production planning and control, and a commercial area manager.

4. The empirical study

4.1. The companies' profiles

4.1.1. Company A

This Brazilian capital company was founded in 1972, has an industrial unit in the interior of the State of São Paulo, and has around 420 employees what characterizes the company as medium size. The company produces high pressure boilers (that product represents 97% of the company's revenue), mainly biomass-fueled. Most of the company's clients operate in the sugar/alcohol sector; the company only develops and manufactures tailored products (Engineering to Order).

Within the boilers segment for the sugar/alcohol sector, its Brazilian market share is around 30%. They export boilers to Latin American countries, mainly: Venezuela, Panama and Guatemala. The external market represents 20% of the company's revenue.

Due to the great current expansion of the sugar/alcohol sector in Brazil, the company has steady contracts to develop and produce new products within the next five years. Given this situation, company A reports not having capacity to undertake new product development projects, being outsourcing the only alternative to solve such a contingency.

4.1.2. Company B

Company B, Brazilian capital, is also situated in the interior of the State of São Paulo; its core competence is tailored development (Engineering to Order) of an assorted products portfolio. Main products are: turbines and electric power generators, material handling equipment (for example: rolling cranes, hoists and mining equipment) as well as gas and oil equipment (for example: pressure vessels, gas storage and measurement systems).

This company operates in the capital goods sector, within the heavy equipments niche. It is one of the most important companies in the country, competing with some other seven companies (foreign and domestic). Mostly serves the internal market, whose main customers represent the sugar/alcohol sector, steel mills, hydroelectric power plants, beside industries operating in the petroleum and petrochemical chain.

Company B has around fve thousand employees, two thousand of which work in the industrial plant visited; and around three thousand employees work in the field, mostly assembling, setting up and rendering after sale services to their industrial customers.

4.2. Product development process within companies

In order to assess the PDP management maturity level in the researched companies, it was necessary to diagnose the main activities of that process.

Table 1. PDP elements in the researched companies.

Phase	Company A: main activities	Company B: main activities
Pre-Development	- No articulation exists among products projects to be developed and company's strategy. - Multifunctional team performs risks analysis (mainly regarding costs and schedules), and quality (regarding conformance with specifications) involving products to be developed and manufactured as well as requests for price quotations and the respective proposals. - Due to exclusive product needs, customers are intensively involved in the project events.; - No project performance indicators are established after the decision to develop products projects. That is left to the experience of the employees involved in the project. - There is no rights or wrongs analysis based on past projects, prior to the beginning of a new project; that is dealt with through employees' acquired experience and knowledge.	- Articulation exists among products projects to be developed and company's strategy. - Multifunctional team performs risks analysis (mainly regarding costs and schedules), and quality (regarding conformance with specifications) involving products to be developed and manufactured as well as requests for price quotations and the respective proposals. - Performance indicators are formally established after the decision to develop products projects, mainly based on cost, conformance with specifications and time. - Due to their exclusive product needs, customers are intensively involved during project stages;. - There is no the habit to formally perform rights or wrongs analysis based on past projects, prior to the beginning of a new project; that is dealt with through employees' acquired experience and knowledge.
Development	- After the project authorization, engineering releases the start of the product project activities. - Defines requirements, conception, structure, drawings, utilizes CAD, and dimensions items. Does not utilize methods like FMEA and QFD. - Informal project assessment is performed throughout the project development (product construction). - The product itself is the only unit produced, tested, reworked if necessary, validated and installed at the industrial customer's. - Product launch planning occurs aiming at timely development conclusion and installation at the industrial customer's as contractually established.	- After the project authorization, engineering releases the start of the product project activities. - Defines requirements, conception, structure, drawings, utilizes CAD, and dimensions items. Does not utilize methods like FMEA and QFD. - Project assessment is performed throughout the project development (product construction) by comparison to performance indicators established in the project. - The product itself is the only unit produced, tested, reworked if necessary, validated and installed at the industrial customer's.
Post-Development	- Technical Assistance verbally reports to the company problems the developed and produced products presented in the field.	- After product development and installation at the industrial customer's, company collects product in use informations, so as to improve future projects. - Commercial and technical assistance functions monitor and collect informations on the product performance at the industrial customers'. - Those informations are fed into the company's information system (mainly MS Project), which is accessed by all the areas involved in products development.

To meet the intended purpose of this research, dealing with companies which develop and produce tailored products, the study will consider the following phases and ranges: pre-development, as the product project planning activities; development, as product project activities; and post-development, as activities carried out after product installation at the industrial customers'. Table 1 synthesizes the main PDP management activities within the companies.

4.3. Results and analysis

Grounded on the analysis of the activities carried out by the companies to perform new products development, next paragraphs will discuss some outstanding practices. Company A seeks to steer PDP activities, mainly through knowledge and experience of the individuals involved in those activities, thus, that company's steering process is not predictable and not even controllable. On the other hand and starting from formalized PDP activities, company B seeks to make it predictable and controlled.

Informality and unpredictability to conduct PDP in company A are evident, as shown in Table 1; company assesses the new product development project in an informal way, utilizing just the indicators of conformance to specifications and deadlines in the project conduction. Furthermore, those are performed mainly utilizing employees' knowledge and experience without greater concern with formalized criteria involving steering, assessment, measurement, control and improvement of the company's PDP activities.

When starting a new project, company A does not carry out rights or wrongs analysis of past projects; that is approached to only through knowledge and experience

Table 2. Maturity levels in management of product development (Companies A and B).

Phases	Company	Maturity Levels				
		Initial	**Managed**	**Defined**	**Quantitatively Managed**	**Optimized**
Pre-Development	A		- No project performance indicators are established after the decision to develop products projects. That is left to the experience of the employees involved in the project. -There is no rights or wrongs analysis based on past projects, prior to the beginning of a new project; that is dealt with through employees' acquired experience and knowledge.		- Multifunctional team performs risks analysis (mainly regarding costs and schedules), and quality (regarding conformance with specifications) involving products to be developed and manufactured as well as requests for price quotations and the respective proposals.	
	B		- There is no the habit to formally perform rights or wrongs analysis based on past projects, prior to the beginning of a new project; that is dealt with through employees' acquired experience and knowledge.		- Multifunctional team performs risks analysis (mainly regarding costs and schedules), and quality (regarding conformance with specifications) involving products to be developed and manufactured as well as requests for price quotations and the respective proposals. - Performance indicators are formally established after the decision to develop products projects, mainly based on cost, conformance with specifications and time.	
Development	A	- Informal project assessment is performed throughout the project development.		- Defines requirements, conception, structure, drawings, utilizes CAD, and dimensions items.		
	B			- Defines requirements, conception, structure, drawings, utilizes CAD, and dimensions items - Project assessment is performed throughout the project development (product construction) by comparison to performance indicators established in the project.		
Post-Development	A		- Technical Assistance verbally reports to the company problems the developed and produced products presented in the field.			
	B				- Commercial and technical assistance functions monitor and collect informations on the product performance at the industrial customers'.	- After product development and installation at the industrial customer's, company collects informations on the developed project, so as to improve future projects. - Those informations are fed into the company's information system, which is accessed by all the areas involved in products development.

already acquired by the employees. Therefore, success in this company depends on individual talents and efforts rather than on a systematic process management, what makes it unstable.

However, company A is about level 2 (managed) of the CMMI model in conformance with that model's assumptions; within its activities to steer PDP, the company seeks to plan and control that process, mainly by utilizing the knowledge and experience of individuals involved in the development process.

Following the CMMI model recommendations, company A should first reach level 3 (defined) to increase its current PDP maturity level. Thus, the company should formalize and standardize to the detail all the activities and performance indicators associated to that process, as well as involve employees in those formalizing and standardization activities.

In turn, company B, besides having the PDP activities already formalized, also established indicators associated to that process: costs, conformance with specifications and dead lines, which are approved by the team involved in the project pre-development phase. Those indicators are systematically controlled and assessed during the project conduction.

After the product development, construction and delivery to the customer and in view of future projects to develop, company B, seeks to collect information and understand strengths and weaknesses detected while carrying out that project aiming at repeating successes and avoiding commit the past mistakes.

Nevertheless, it was evident those informations were not systematically analyzed prior to the product development (Pre-development Phase). A good practice, related to the PDP execution improvement, would be to take advantage of the informations collected and recorded in past projects to support future projects development; such attitude would imply changes in behaviors and work routines.

Consequently, company B reached level 4 of the CMMI model. Results in Table 1 show the company performs formalized products development activities and adopts performance indicators, what makes that process predictable and controlled. Besides, company can use those quantitative data to orient improvement actions applied to PDP management.

As regards the organizational structure for PDP management, both companies utilize multi-functional teams, especially during the pre-development phase, prior to the approval of projects execution. Such event occurs with the participation of areas representatives, who furnish informations and opinions on the proposed product project.

Possibly, the adoption of such practice is mainly due to the need to minimize risks, whether financial or to the company's image. That is because, those companies generate the product supply contract including, besides price and delivery date, all its technical specifications. It is worthy to mention that, after the customer's acceptance, companies may not refuse the dimensions proposed and contractually agreed upon, even having to face future problems.

Regarding that issue, functional integration is helpful to products development within companies, since people bring along different perspectives, which leads to a greater experience and knowledge exchange, resulting in a better prevision and PDP activities planning. Regarding the pre-development phase and as observed in both companies, functional integration minimizes typical problems normally taking place in more advanced phases of that process, for example: lack of a given raw material in the market, production, unavailable technology, product delivery and assembly at the customer's.

Because of the fact that both companies develop and produce tailored products, it is not necessary for them to apply some recommendations available in the literature on PDP management, such as Quality Function Deployment - QFD (CLARK; WHEELWRIGHT, 1993; CLAUSING, 1994; ERNST, 2002), due to the uniqueness of the developed product. Additionally, in companies having that characteristic, intense customer's involvement is normal during the project phase, because it is the customer who provides the specifications of the product to be developed (KAMINSKY; OLIVEIRA; LOPES, 2008).

Table 2 shows some evidences that indicate the management maturity level in the researched companies.

Although it is difficult to determine objectively the maturity level of PDP management in these companies, it can be said that the company A is predominantly found in level 2 and, B in level 4. Analyzing the maturity level and improvement in the companies' new product development it was observed, in company A, the necessity of more formalization of PDP activities. The company should look initially for the practices systematization and creation of PDP performance indicators.

In the company B, it was verified that the inclusion of practices such as the adoption and institutionalization of measurement and continuous improvement in new product development and also the implementation of policies for knowledge management still in pre-development phase, could be responsible for the increased maturity and thereby improving performance of the company's PDP.

5. Conclusion

The CMMI model, which is specifically oriented to the assessment of maturity levels in software development processes, can be applied to the development process of industrial products, as evidenced by these cases.

The application of that model is also possible in the development of tangible products, since it can assess and

allows the diagnosis of the existing PDP maturity level, as well as identify and plan the next practices the company may utilize to improve that level.

Considering the oligopolistic business environment that company B operates in, a better PDP management, which will result in an advanced maturity level, is fundamental for the company's survival and competitiveness. Large domestic and multi-national companies impose intense competition; furthermore, company B's products are fundamental for the manufacturing processes operated by other segments' industries, which demand the supply of quality assured products.

Differently, medium size company A supplies capital goods equipments to the sugar/alcohol market, which is currently growing at an expressive rate in Brazil. Such a situation does not urge this company to improve its PDP management, since the favorable market conditions have ensured development and fabrication contracts within a five years horizon. However, the model of company A analyzed in this study showed the current standard of performance and identify improvements of the company's PDP activities.

Considering that company B is at the relatively advanced maturity level of PDP management, the analysis of this specific case diverges from Vermulum's (1995) work, as regards products development, where the author declares the Brazilian capital goods companies have insufficient qualification for those activities.

This exploratory research is grounded on the two selected cases, aiming at the initial understanding of the maturity levels for PDP activities in companies which develop tailored products. This study is expected to stimulate future researches on this subject, whose results will have the potential to improve and disseminate maturity models, mainly focused in practices, methods, and tools for the PDP management, taking into account the specific needs of companies which develop tailored products.

6. References

AGUILAR-SAVÉN, R. S. Business process modeling: review and framework. **International Journal of Production Economics**, v. 90, p. 129-149, 2004.

AMARAL, D. C.; ROZENFELD, H.; ARAUJO, C. A case study about product development process evaluation. In: LOUREIRO, G. C.; CURRAN, R. (Ed.). **Complex systems concurrent engineering**: collaboration, technology innovation and sustainability. London: Springer–Verlag, 2007.

BAXTER, M. **Projeto de novos produtos**: guia prático para o design de novos produtos. 2. ed. São Paulo: Edgard Blücher, 1998.

BRYMAN, A. Integrating quantitative and qualitative research: how is it done? **Qualitative Research**, v. 6, n. 97, 2006.

CAFFYN, S. **Continuous improvement in new product development process**. Thesis (PhD)-University of Brighton, 1998.

CHENG, L. C.; MELO FILHO, L. D. R. Gestão de desenvolvimento de produtos (GDP) e o método de desdobramento da função qualidade (QFD). In: CHENG, L. C.; MELO FILHO, L. D. R. **QFD**: desdobramento da função qualidade na gestão de desenvolvimento de produtos. São Paulo: Blücher, 2007a. p. 1 -35.

CHRISSIS, M. B.; KONRAD, M.; SHRUM, S. **CMMI**: guidelines for process integration and product improvement. USA: Addison–Wesley, 2003.

CLARK, K. B.; FUJIMOTO, T. **Product development performance**: strategy, organization and management in the world auto industry. Boston: HBS Press, 1991.

CLARK, K. B.; WHEELWRIGHT, S. C. **Managing new product and process development**: text and cases. New York: The Free Press, 1993.

CLAUSING, D. **Total quality development**: a step-by-step guide to world-class concurrent engineering. New York: Asme, 1994.

COOPER, R. G. Managing Technology Development Projects. **IEE Engineering Management Review**, v. 35, n. 1, p. 67-76, 2007.

COOPER, R. G.; EDGETT, S. J.; KLEINSCHMIDT, E, J. New product portfólio management: practices and performance. **Journal of Product Innovation Management**, v. 16, p. 331-351, 1999.

CREVELING, C. M.; SLUTSKY, J. L.; ANTIS, D. **Design for six sigma**: in technology & product development. New Jersey: Pretince Hall, 2003.

CROSBY, P. B. **Qualidade é investimento**. 6. ed. Rio de Janeiro: José Olympio, 1994.

DAVIES, A.; HOBDAY, M. **The business of projects**: managing innovation in complex products and systems. Cambridge University Press: Cambridge, 2005.

DOOLEY, K.; SUBRA, A.; ANDERSON, J. Adoption rates and patterns of best practices in new product development. **International Journal of Innovation Management**., v. 6, n. 1, p. 85-103, 2002.

DOOLEY, K.; SUBRA, A.; ANDERSON, J. Maturity and its impact on new product development performance. **Research in Engineering Design**, v. 1, n. 1, p. 23-29, 2001.

ERNST, H. Success factors of new products development: a review of the empirical literature. **International Journal of Management Reviews**, v. 4, n. 1, p. 1-40, 2002.

FRASER, P.; MOULTRIE, J.; GREGORY, M. The use of maturity model/ grids as a tool in assessing product development capability. In: ENGINEERING MANAGEMENT CONFERENCE - IEMC´02, 2002. **Proceedings**...

GRIFFIN, A. PDMA Research on new product development practices: updating trends and benchmarking best practices. **Journal of Product Innovation Management**, v. 14, p. 429-459, 1997.

HAYES, R. et al. **Operations, Strategy, and Technology**. United State of America: John Wiley & Sons, 2004.

JIANG, J. J. et al. An exploration of the relationship between software development process maturity and project performance. **Information & Management**, v. 41, p. 279-288, 2004.

JUGEND, D. **Gestão da integração entre desenvolvimento de produtos e de tecnologias**: estudo de casos em empresas industriais de médio porte e intensivas em tecnologias. 2010. 188 f. Tese (Doutorado em Engenharia de Produção)– Universidade Federal de São Carlos, Departamento de Engenharia de Produção, São Carlos, 2010.

KAHN, K. B.; BARCZAK, G.; MOSS, R. Perspective: establishing an NPD best practices framework. **The Journal of product innovation management**, v. 23, p. 106-116, 2006.

KAMINSKY, P. C.; OLIVEIRA, A. C.; LOPES, T. M. Knowledge transfer in product development process: a case study in small and medium enterprises (SMEs) of the metal-mechanic sector from São Paulo, Brazil. **Technovation**, v. 28, p. 29-36, 2008.

MOULTRIE, J. P.; CLARKSON, J.; PROBERT, D. Development of a design audit tool for SME. **The Journal of Product Innovation Management**, v. 24, p. 335-368, 2007.

PUGH, S. **Creating innovative products using total design**: the living legacy of Stuart Pugh. Massachusetts: Addison-Wesley, 1996.

QUINTELLA, H. L. M.; ROCHA, H. M. Nível de maturidade e comparação dos PDPs de produtos automotivos. **Revista Produção**, v. 17, n. 1, p. 199-217, 2007.

RESENDE, M. F. C.; ANDERSON, P. **Mudanças estruturais na indústria brasileira de bens de capital**. Brasília: IPEA, 1999. (Texto para discussão, n. 658).

ROZENFELD, H. et al. **Gestão de desenvolvimento de produto**: uma referência para a melhoria do processo. São Paulo: Saraiva, 2006.

SOUDER, W. E.; BUISSON, D.; GARRET, T. Success through customer-driven new product development: a comparison of US and New Zealand small entrepreneurial high technology firms. **Journal of Product Innovation Management**, v. 14, p. 459-472, 1997.

VERMULUM, R. O setor de bens de capital. In: SCHWARTZMAN, S. (Org). **Ciência e Tecnologia no Brasil**: Política Industrial, Mercado de Trabalho e Instituições de Apoio. Rio de Janeiro: Fundação Getúlio Vargas, 1995. p. 149-178.

VERMULUM, R.; ERBER, F. Cadeia: bens de capital. In: ESTUDO da competitividade de cadeias integradas no Brasil: impactos das zonas de livre comércio. Unicamp–IE–Neit, MDIC, Finep, 2002. Nota técnica final.

YIN, R. K. **Estudo de caso**: planejamentos e métodos. 3. ed. Porto Alegre: Bookman, 2005.