Continuous improvement of product development process: a PLM strategy tool

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Abstract: There are different understandings of Product Lifecycle Management (PLM). This paper defines it as a strategy to integrate all company activities and decisions during the life of a product. To apply this strategy is fundamental to organize and systematize a Product Development Process (PDP) through continuous improvement (CI) and implementation of PDP reference models. This article describes a case of product development systematization in a specific automotive enterprise. During the case research, recent data was collected on the company's performance and history information regarding changes on its PDP model and practices. This research suggests the hypotheses that it is important to implement a systemic continuous improvement process (CIP) on PDP and to analyze it in order to promote the PLM strategy.

Keywords: product development process, systematization, product development performance, reference model.

1. Introduction

Nowadays we can find different meanings of Product Lifecycle Management (PLM) on the literature. In the organizational area, it is usual to see PLM as a strategy to integrate all company activities and decisions during product life. The final goal is to improve product perfomance on the market taking right decisions, based not only on product development data but also considering whole product life in the market. Many PDP models available on the literature don´t consider total scope of PLM; instead of it, they describe product development finalyzing just after is launch. Newer researchs are now considering whole product life and this is the main reason why PLM was born.

Acoording a strategic point of view, PLM can be considered as a way to integrate and and systematizate PDP and related enterprise processes. Available literature suggests that to get an effective systematization it is necessary to improve continuously the PDP. Many PDP models describing phases, best practices and methods for product development had been discussed a lot in the agenda (BAXTER, 1995; COOPER, 1993; PUGH, 1978; ULLMAN, 1997; ULRICH; EPPINGER, 1995; WHEELWRIGHT; CLARK, 1992).

Even considered as a key-point of success, it is not commum to find companies using specific methodologies to support the PDP systematization and Continuous Improvenment (RUY; ALLIPRANDINI, 2007). In addition, a small number of studies can be found discussing effective PDP models implementation, considering all steps this implementation represents and also how to proceed to get it.

Actually, automotive companies have good maturity level on PDP, if compared with other market segments. Main input that originated this article was the case of product development systematization in a specific automotive enterprise. During case research it was collected recent data of company performance and history information regarding changes on its PDP model and practices.

Through a holistic case study (YIN, 2003), this paper describes actions and practices, and analyzed the impact on performance in order to identify aspects to be studied at theory. To analyze PDP systematization and performance it was selected six concluded product development projects which were developed on two different periods of time: before and after to implementation of a set of PDP systematization actions. Results of the two project groups were compared through some key performance indicators, previously defined.

2. Product lifecycle management and reference models

There are differente meaning for PLM. Through a simple view it is possible to identify two different definitions, as follow:

- PLM as a tool: some authors (KAIYU, 2006; KIM et al., 2006; LIU et al., 2006) refer to PLM as a specific kind of application or information technology, capable to integrate product data during

whole live (GOMES; VALLEJOS, 2007). Main goal of this technology is to improve process performance using a product data control do processo por meio do controle dos dados do produto. First of them had a strong focus on Product Data Management (PDM) (STARK, 2005).

- PLM as a strategy: some authors (GUELERE FILHO; ROZENFELD; OMETO, 2007; HAHN; AUSTING; STRICKMANN, 2007; SPERANDIO; ROBIN; GIRARD, 2007) believe PLM is a particular way to get benefits on performance by na integrated product data management, considering all business process through the company to get some decision.

This second definition is more relevant if we consider a perspective of organizational factors that can affect PLM. Software vendors are members of this group and it incluses one of the most cited definion, proposed by Cimdata (2002, p. 1), that define as

> [...] A strategic business approach that applies a consistent set of business solutions in support of the collaborative creation, management, dissemination, and use of product definition, information across the extended enterprise from concept to end of life integrating people, processes, business systems, and information.

This research considers PLM as a strategic approach that focus the improvement of product development process performance by the integration of internal and external agents of this process, such as people, technology information and organization; its integration happens in a colaborative way with the goal to continuous improvement of PDP as a business process (productivity, cost, timing, quality and customer added value). To apply this strategy is a complex process with many pitfalls and uncertainties. A practical way to make it happens is to map, improve and standardize the Product Development Process, using reference models.

Product development process (PDP) is not a process made by independent activities and under the responsibility of marketing, production, process and product areas anymore (COOPER, 1993). Nowadays companies understood to get an efficient product development it is necessary to get a multifunctional team working together, following same directions and goals. To apply this approach it is essential to use a formal PDP that means to produce a map describing new PDP and where all multifunctional team understands that map and follow it, focused in just one final goal. Business process modeling or enterprise integration provides a set of techniques to turn it possible to be done and followed (BAXTER, 1995; MERTINS; JOCHEM, 2005; KALPIC; BERNUS, 2002). Clark and Fujimoto (1991)firstly demonstrated the importance of this approach in a specifically case study if this area. Authors explain how reference models can be helpful in activities related to project, management and execution of business process. Since emergence of business processes approach on product development, more or less elaborated reference models have been proposed to help professionals to identify and implement best practices (CONDOTTA, 2004; COOPER, 1993).

3. PDP sistematization and continous improvenment

To be effectively systematized, PDP needs to be reviewed into companies. It happens by activities which belong to PDP or not; as example, activities which belong to continuous improvement process (CIP) can be applied for all process into a company, once CIP is a supporting process thought all others. This research considers activitiies from both processes (PDP and CIP) can help PDP systematization. In this context, standardization of activities is one of key-points to get systematization, once if activities are standardized they can be faster understood, used and multiplied into the company. As consequence, standardization can eliminate wastes on product development process.

It is already available some published researches that suggest PDP systematization based on a reference model (CONDOTTA, 2004; ROZENFELD et al., 2006; STARK, 2005; ULRICH; EPPINGER, 1995; ULLMAN, 1997); main point is that they don't discuss or analyze their effective applicability or implementation.

Brigantini and Miguel (2007) describe a automobile company case of product development process improvement, using a reference model. The authors demonstrated the capacity of this strategy to indicate the improvenments directions. But couldn´t demonstrated the benefits and results of these approach. Otherwise, Ruy and Alliprandini (2005) described the learning process performed into the project for three excellence companies and demonstrate a lack into the translation of these learnings into chages at the product development process reference model: the PDP systematization.

Condotta (2004) developed a research with focus in a re-organization on PDP model management but it still doesn´t discuss applicability and implementation enough. Many activities and tools discussed by the literature – specially applied on production process into companies – can also be applied to PDP, if they are right adequated to its particular characteristics such as criativity and intangibility. Some of them are described by: Benchmarking; 5S Program; Lean Thinking; Kaizen culture; Stage-Gate, etc.

To get a review and latter an improvement on product development process practices into companies, CIP activities are determiners of success. In addition those activities can promote that review once it allows activity cadence organization, easily inputs and outputs identification of each phase of PDP, standard of activity execution every project

it should be done, elimination of wastes or not added-value activities, etc.

The companies already noted competitive advantage improving PDP and in those ones it is possible to see a special attention on employee skills and knowledge about continuous improvement practices, activities and mainly culture. Examples are Japanese automakers. Some researches as Lee and Dale (1998) believe it can come firstly from employees training and some others believe it come from high level managers, as Wheelwright and Clark (1992, 1995).Both examples believe it is fundamental to capture knowledge from all parts of the company, compile them and create a base of intelligence to be re-used every time it is necessary (LEONARD-BARTON, 1995). It will avoid many wastes with effort to solve some challenge when it appears during a product development. Into automotive world there are many literatures which already mention importance of continuous improvement activities into PDP. We can mention here ISO/TS16949 and QS9000 specification and APQP (Advanced Product Quality Plan) Manual. The last one describes exactly PDCA (plan, do, check and act) cycle, which is a Deming disseminated theory about CI.

4. Differences between CI implementation on manufacturing process and PDP

As already presented by literature, continuous improvement activities were firstly implemented on manufacturing process. Nowadays it is still difficult to implement CI on PDP once its characteristics of creativity and intangibility turns analyzes of CI implementation results more difficult to be saw. It looks like we don't have improvements on the process once we can't take or see them due to lack of numbers to compare. This is the biggest paradigm that should be broken first of all. Caffyn (1997) describes those differences as follows:

- PDP is an iterative process. It means there is a natural cycle, project-build-test-optimize, to improve solution. That is why it is difficult to identify when some activity is a waste or not once time spent can be considered as a new important knowledge to the company;
- Intangible activities on PDP are critical points once it is difficult to measure their results;
- On manufacturing process once you execute an improvement you can see its results physically; on the other side, on PDP most of times you can't see its results because it is not an impact in a machine, part or place but an impact of information or knowledge;
- PDP activities are usually longer then manufacturing ones and due to this it is not fast to see results of improvements;
- PDP culture has innovation as main goal and that is why standardization is not always easy to implement; each activity result is unique;
- Key indicators on manufacturing process are always reference to a number, different than to PDP. Example: you can spend more time in an activity and it can be good to the project instead of be a waste. It depends on the results (information or knowledge) it brought.

Rosenau (2000), Liu et al. (2006) e Rozenfeld et al. (2006) who already discuss CI activities on PDP although they still don't apply them to PDP in a real case.

5. Mechanisms that can support CI on PDP

Even finding many difficulties during continuous improvement implementation on PDP there are some mechanisms that can support and facilitate this implementation. Within this research mechanism is defined as an arrangement and action by which something is produced or achieved. Below we described some of them. There are some others available on literature are not described here because they don't match with the scope of this research.

- Benchmarking activities: go in or out of company to identify best practices and take them to a new product development;
- 5S Program: task force by the team to reduce all kind of wastes or not value added things / activities;
- Lean Thinking / Kaizen culture: main Japanese methodology to identify wastes, firstly implemented on manufacturing process. It began to be discussed by literature about how to implement it on PDP but no case-studies were identified until now;
- Stage-Gates: this methodology is currently using by many companies during a product development. Many authors as Cooper (2001) and Silva (2004) discuss small variation on the usage but main goal is to evaluate development status and give a strategic direction. That is also an opportunity to analyze, share and compile lessons learned and best practices. Some companies – such as the one we analyzed for this paper – already use standard forms and as part of information to be completed there are some fields to feed a database to be latter consulted. This methodology can be considered a mechanism to improve PDP once it can (COOPER, 1993) improve team work; avoid reworks, improve number of launch with success; and reduce until 30% development timing.

Ruy and Alliprandini (2005) describe three Brazilian excellence cases of learning on product development. The learning from projects was stored tacitly in the individuals, in two of them. The authors point a lack of translation to the

team and no changes in the product development process reference model. The last case, entitled Case A, have had changes in the product development process at the end of the year and thus post-project learning. Nevertheless the authors didn´t note structured methods to secure it.

6. Objectives

The literature review demonstrated continuous improvement is a key-element for product development process (PDP) success. In addition of this fact, continuous improvement process (CIP) can be considered a key-element to get PDP systematization if companies follow CIP activities. Even many researchers already discuss CIP and also PDP, it was not found a robust research – including a case-study – of this relationship. Other challenge is analyze how to control PDP after systematization to keep it as an effective action. Once answered those question companies will be able to improve way they develop and control new products and its activities.

We decided to make a research which could contribute to this lack on literature, taking as the main goal understand and better define relationship between PDP and CIP. The paper present the case of an automotive company with a recent experience with PDP systematization. Quantitative and qualitative results are compiled and compared below.

The alternative to chose an automotive company is explained with actual market scenario where this segment frequently demonstrate a high level of maturity in product development process if compared with other segments.

After choose the company, we made a case-study where it was possible to characterize which CI activities were done during PDP systematization, identifying the ones belonged to PDP and others belonged to CIP. Just after this analyzes, it was studied impacts of the execution of activities comparing results of three product development projects before activities implementation and three projects after it.

Main objective of this research is to characterize this relationship between PDP and CIP, understanding which activities can contribute to it. So, contributions are:

- Review the literature about relationship between PDP and CIP, looking for activities which can be used to get PDP systematization by CIP support;
- Verify the applicability of those activities in a case-study and effective impacts on product development projects results.

7. Method

This is a qualitative research because descriptive and meaning and process are main focus and it is not necessary statical methods or similar tools (LAVILLE; DIONE, 1999). The paper is considered an exploratory research because the goal is to answer quais such as which fenomenus can be identified on the implementation of continuous improvement on PDP and what is the relationship between PDP and CIP process. This research also describes activities from literature and it happens in a company, exploring those subjects, Figure 1.

Once defined goal of this research, it was established its strategy, being divided in five steps:

- Research on literature about continuous improvement activities and mechanisms to PDP systematization;
- Documentation analyzes about PDP implemented on that company and the history of the implementation;
- Description of their PDP model and comparison with the ones available on literature;
- Selection of key people to be interviewed (at least two years working on that responsibility and from different hierarchy levels in the organization);
- Selection of projects to be a source of information and data; the case-study of PDP systematization impacts thought project results, including activities from PDP and others from CIP used during systematization; contribution and conclusion.

To get better data for the research analyzes during case-study people from different hierarchy level and department. It was also made analyzes of many project documentation (hard copies and digital ones), including procedures and databases, when available. Researchers personally followed many hours of activities into the company, to get a better understanding of data and the real scenario.

Main method of this research is case-study because it is "a research strategy that includes not only selection of data but also analyzes of its results" (YIN, 2003, p. 21).

The projects was defined to verify the impact after and before the systematization using continuous improvement activities. To get a truth conclusion, it was selected quantitative key performance indicators, equals for selected projects of products developed before and after systematization of PDP. It was selected six differente projects, divided in two groups: three belong to the group 1 (from 1999 to 2002), which means projects made before systematization and other three belong to the group 2 (from 2002 to 2006), or after this systematization. Figure 2 can better represent it.

Key performance indicators defined to make analyzes are represented by: forecast versus actual budget and timing; resources unit for each project (forecast × actual), number of nationalization of involved components (forecast × actual), number of formal customer complaints and product fails after production.

Selected projects were analized comparing pairs with same complexity level and which belong to the same product line, being one project for each group. Projects from each group should be developed during same period of

time and they all should be completed before this research happens.

As criteria for identification and selection of activities it was defined to include: a) the ones found on the literature which came from interviews and documentation analyzes; b) the ones should be applied to PDP as a business process, no matter if they belong to PDP or CIP as a support process, although the research manage PDP and CIP activities separately.

After divided by PDP or CIP activity, it should be classified as: 1) *formal*: belongs to PDP model or related procedures with right frequency, methodoly and responsibles to be done; 2) *Ad-hoc*: can or can not belong to PDP model. There is a known methodology and is done when necessary with no matter about frequency or responsible; Not exist:

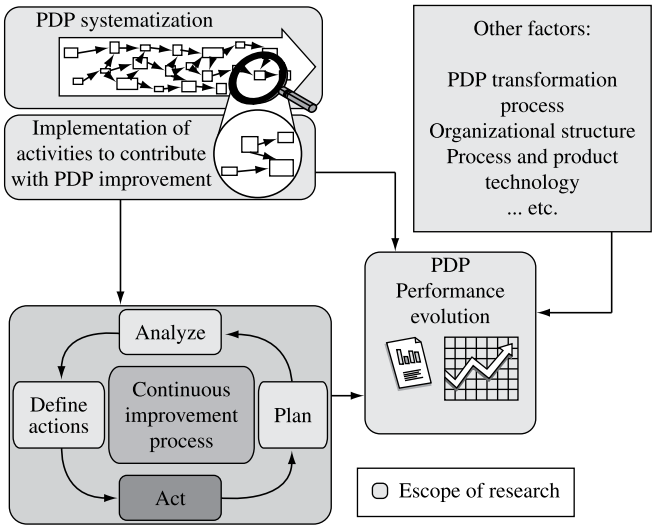

Figure 1. Research model reference.

acitivities found on literaure but not identified in the case study.

8. Case-study

The case study was conducted in a Brazilian unit of a worldwide auto parts and partially presented at Agostinetto and Amaral(2007). Site selected is a technical center located in Brazil since 1999. First product development activities under local team responsibilities happened in 2001, when it was allocated first product engineers. Before this all responsibilities were located in the USA and Brazilian team was responsibly only to support American team. In 2002 it was established a Project Support Office (PSO) to support developments; for those projects it was nominetad local project managers as a strategy to increase business in Brazil. In 2006 company used to have 35 projects, 25 advanced ones (strategic developments didn´t sold) and many business opportunities for competition in the market.

Since the beginning of product development activities (2002) until the end of this research it was possible to see a lot of change on PDP and also many continous improvement activities being implemented thought PDP activites.

First important action they took was to stablish the utilization of PDP global reference model on that site. It is presented on Figure 3.

The reference model is called *Phase-Gates*. It was implemented following north america headquarter practices to analyze development during its evolution and to give direction (from high level management to project team and project manager). Directions could be: stop developing, keep working or re-make / re-submit. There are two types of gate-reviews: technical ones, called *design reviews* represented by lozenges on and management gates - called

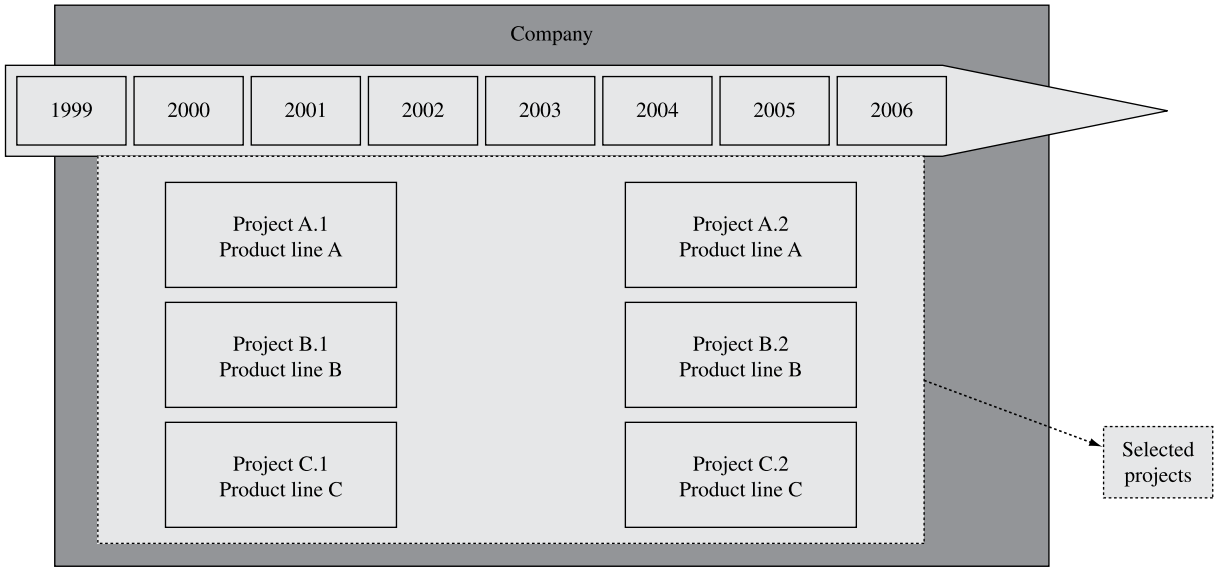

Figure 2. Research sample. Fonte: Agostinetto and Amaral (2007).

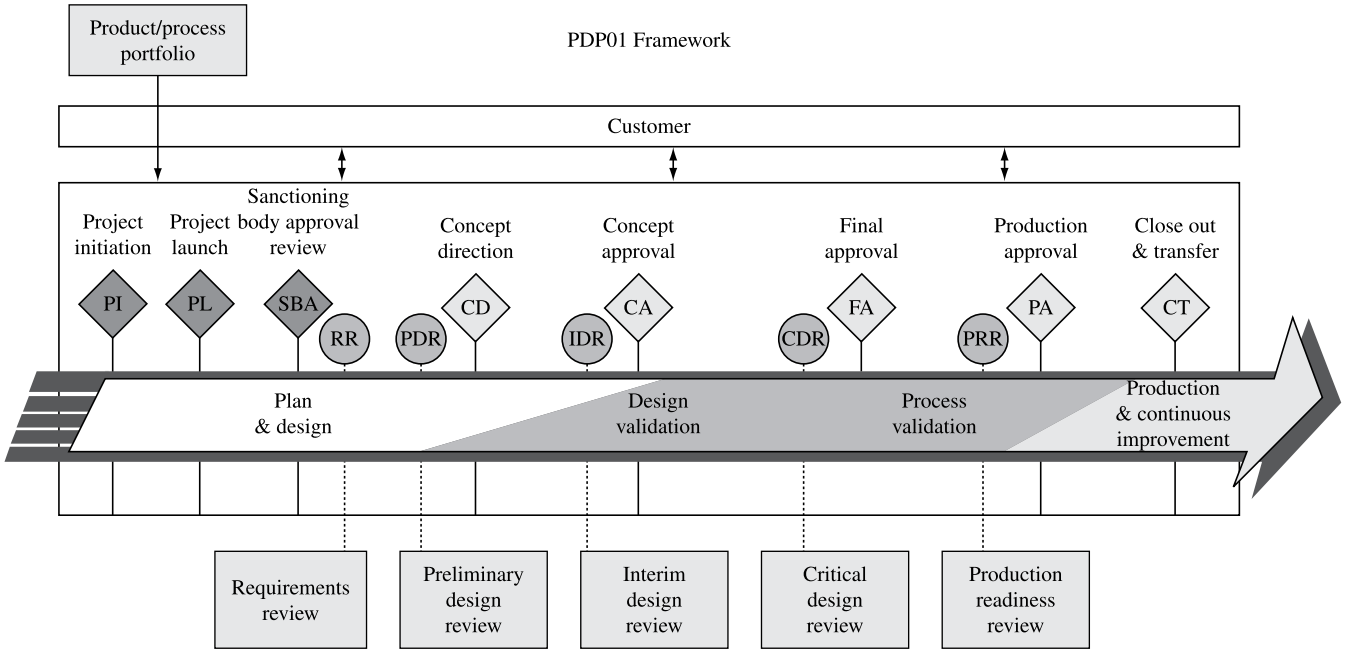

Figure 3. PDP reference model into case-study. Source: documents from the enterprise.

project reviews - represented by circles; main goal of project review is to verify if actual status of a specific project is aligned wit initial plan presented by the scope statement by the beginning of the project.

One important improve they implemented is to stablish a communication with customer during all development guarantying its participation and being sure they are following voice of customer during the project.

PDP model of the company empathizes plan and design begin phases. It also suggests a global project categorization by types (A, B, C and D), where A category represents a most complex product and process development and D represents a routine project. Each category has its own requirements and steps to be followed.

9. PDP systematization into the site

Product development process adopted by the company was firstly published by North American headquarter in 1995, just after APQP manual was published by automakers. Model proposal was to define a standard for all new product development project, ensuring conformance with requirements from customers.

In 1997 PDP model was reviewed at the first time and again in 1998. Most recent PDP model revision happened in 2001, when it was eliminated micro-activities and also the ones considered as not added-value to customer. This revision represented a decrease of more than 50% of activities, if compared with previous revision. On this new scenario, all required activities from PDP model represented only 105 activities.

First re-organization into product development department was held in 2001, when – by continuous efforts from Brazilian high level management – it was nominated first product engineers and project managers in Brazil. From 2003, it was formalized a parallel structure to support product developments. It was called *Project Support Office* (PSO) and it was designated an independent supervisor. This group standardized and created practices to control, organize and make new product development activities, implementing stantards to forms, procedures, activities and also responsibilities. On that time, it was held many training sessions to the hole team to share knowledge. PDP systematization was leaded and facilitated by PSO; they identified gaps, defined and implemented plans and verified their efficiency with performance indicators. Many post-project audits were held to capture new knowledge, lessons learned and best practices and to turn them available to the rest of team and company, when necessary.

Main problem regarding PDP model into the company refers to people from multifunctional team but who work outside that site. To solve those issues, PSO team had established activities and tools as a set of efforts demonstrated by Figure 4, including process culture diffusion, training e projects audits.

Figure 4 demonstrates that change was more intensive done last three years.

10. PDP systematization and projects perfomance

As previously explained, to analyze effectiveness of PDP systematization into the site it was firstly selected

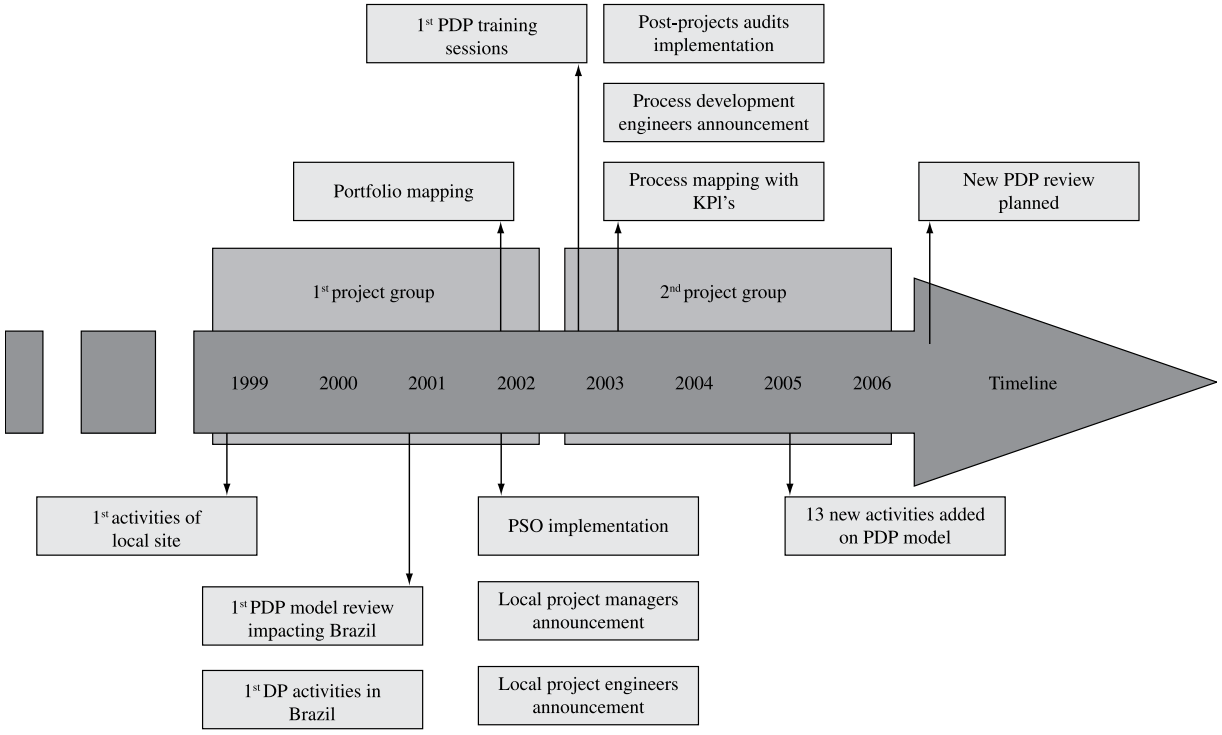

Figure 4. Examples of PDP systematization steps into case-study. Fonte: Agostinetto and Amaral (2007).

six different projects, which were developed in two different periods of time: before and after a set of PDP systematization. Results of the groups were compared through key performance indicators already detailed.

After a research on available literature it was identified activities and tools suggested by literature that can facilitate PDP systematization. Examples are listed below; complete list can be found on Agostinetto (2006):

- Use electronic mock-up to simulations;
- Use quality tools to ensure performance: FMEA, QFD, DFE, etc;
- Define specific department to support product developments;
- Define and monitor performance key-indicators;
- Implement *stage-gates* methodology;
- Implement a depository of lessons learned;
- Use concurrent engineering;
- Define programs to stimulate continuous improvement practices.

Analyzing presented results by the number of found activities and tools in each project group (Figure 5 and Figure 6) we have a significant increase of formal activities on the same time we have a decrease of ad-hoc and not-exist ones. It represents that the effort located to PDP systematization resulted in a formalization of most activities and tools they had or they knew. Regarding key-performance indicators we have:

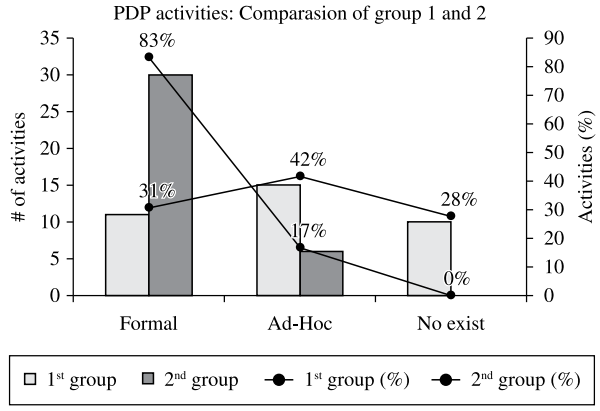

Figure 5. PDP activities: comparison of two project groups.

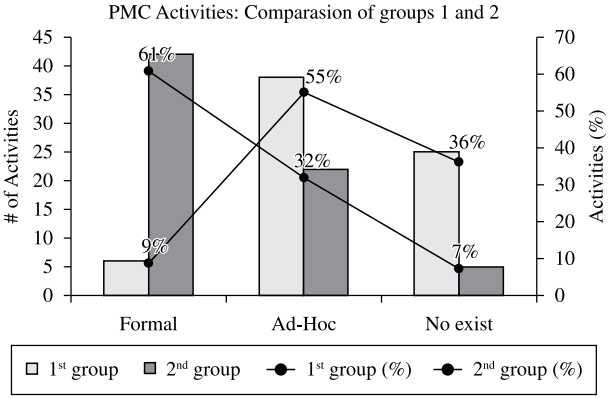

Figure 6. PMC activities: comparison of two project groups.

Table 1. Key-performance indicators from projects.

	Product line A		Product line B		Product line C	
First project group (1998-2002)						
	Project A. 1		**Project B. 1**		**Project C. 1**	
	Forecast	**Actual**	**Forecast**	**Actual**	**Forecast**	**Actual**
Category	B	B	B	B	C	C
Involved people	15	12	30	30	9	9
Timing	2 years	2 years	3 years	3 years	14 months	14 months
Budget	100	90	100	100	Not defined	Not defined
Nacionatization	0%	0%	Not defined	3%	10%	10%
Fails aftermarket	Not defined	1000 ppm	Reduction of 70%	Reduction of 70%	0	0
Formal complaints from customer	0	0	0	0	0	0
Second project group (2002-2006)						
	Project A. 2		**Project B. 2**		**Project C. 2**	
	Forecast	**Actual**	**Forecast**	**Actual**	**Forecast**	**Actual**
Category	B	C-B	B	B-A	C	C-B
Involved people	10	10	20	20	9	9
Timing	2 years	2 years	2 years and half	2 years and half	2 years	2 years
Budget	100	90	100	80	100	95
Nacionatization	10%	10%	More than Project 1	35.30%	Not applicable	Not applicable
Fails aftermarket	500 ppm	500 ppm	1000 ppm	445 ppm	1000 ppm	445 ppm
Formal complaints from customer	0	0	0	0	0	0

Fonte: Agostinetto and Amaral (2007).

Results on Table 1 are present in percent and not in real numbers due to confidential requirements. Indicators demonstrate that first projects (belong to the first group) met expectations of the company and the customer because timing, budget and quality requirements were met. By the other side, analyzing all data it is possible to note that goals of the first group were easier than the second group, especially for timing and costs and as consequence, easier to be achieved.

Local responsibilities also increased a lot for the second group once during the first projects they only supported activities in Brazil.

The second group of projects presents better results with compared with the first group and also they have targets more difficult to be achieved. One example is budget defined to the projects.

11. Conclusion

The PLM strategy is not easy to implement. The paper discuss a way to search for that through the Continuouss Improvenment Process of PDP. The Case-study demonstrated that companies models are following literature, but usually after an adaptation in a specific segment such auto parts. Indicators used on case-study validate previous discussion that the implementation of CI activities, contributing to PDP systematization, brings wins profit and reduce development timings, and, in addition, keep the company with competitive advantages.

Project analyzes show PDP systematization brought positive results so that can be important to have a reorganization of complementary processes to PDP. The results suggest that have a systematized continuous improvement it is necessary and should be used to introduce continuous changes in order to find PLM targets.

The second contribution is that the paper demonstrated the possibility of define measurable indicators to verify actual and forecast scenario for PDP systematization, even with its non-measurable characteristics. This could be a interesting them of research to demonstrate the utility of reference models and CI practices.

Analyzing case study results it was also possible to see available projects categories are not enough to describe all projects into portfolio they have. In other words, it is not clear which projects belongs to each category. An evidence is that two of the six analyzed projects were changed their category during the development. And projects behavior was similar, even in different categories, considering first and second groups separately. A better project categorization should be used for researchers interested on repeat or adopt similar method.

A continuation of this research could be a validation of the hypotheses that continuous improvement process needs to be not only a support process but also a systematized process with focus on PDP, once it was demonstrated that continuous improvement activities helped to improve product development results at this case. It could also be analyzed same scenario of other auto parts companies other in companies from other segments.

This could be a interesting way to put the enterprise in PLM direction. However, there isn´t theoretical references combining CIP, PLM and PDP. The creation of theoretical models on this area is an interesting research theme.

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