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# Method for evaluation via benchmarking of the lean product development process

## Multiple case studies at Brazilian companies

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## Abstract

**Purpose** – The purpose of this paper is to describe benchmarking to evaluate the product development process (PDP) from a lean perspective.
**Design/methodology/approach** – The work was conducted by means of case studies at large companies in Brazil that develop products, based on a gap in the literature involving a lack of indicators to diagnose how lean are PDPs considering the principles and practices of the lean approach.
**Findings** – The results indicate in a quantitative manner that the 12 companies of the multiple case study are implementing the lean approach in their PDPs in an isolated or systematic manner through the categories – process, management, structure, people, product, client, supplier and waste.
**Research limitations/implications** – The large companies in the case studies are located in different positions of the supply chain and the year that the company began introducing lean manufacturing was not considered, or the maturity of each firm.
**Practical implications** – Based on the diagnosis, it was possible to propose a set of actions so that the PDP at each company can be structured in a lean manner, improving competitiveness.
**Originality/value** – The main contribution of the study is a simple, useful and reproducible method that has a set of measurable indicators and graphic representation identifying the lean product development practices, as well as a structured guide to the implementation of improvements that allow companies from different sectors to be compared at a national level and also in the international market.

**Keywords** Performance measurement, Continuous improvement, Benchmarking, Operations management, Lean, Industrial performance, Company performance, Product development process
**Paper type** Case study

## 1. Introduction

The product development process (PDP) is one of the main distinctions available to companies that are seeking to gain position in an environment in which the velocity with which products are developed and placed in the market comes to be an important element in competitiveness, mainly because of the high rate of technological change, a

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higher level of demand by clients for quality, the need for the so-called customization of many products, and the diversification of items released (Campos and Silva, 2007).

It has been observed that during the PDP, regardless of the sector in which a company operates, some common problems are found:

- a lack of integration among departments and between departments and the business strategy;
- organizational and communication barriers;
- the time of execution exceeds that which was planned;
- variability in the tasks and method;
- constant reworking;
- relationship with suppliers are not long term with a philosophy of partnership (win-win);
- deficiencies in measuring and control;
- lack of an organized/structured PDP;
- obscure definition of the entrance data (specificities and requirements); and
- no recording of lessons learned and project histories.

This study is justified because it addresses these problems and helps to decrease them at companies by conducting a diagnosis based on benchmarking that identifies the barriers and opportunities for improvement. A diagnosis is used as the initial step for the later implementation of the lean approach to product development that delivers something of value, at lower cost, time and with quality. It is necessary to know the current state, how each company is positioned in relation to the market, and internally, based on a reference model with well-defined indicators and steps. The benchmarking method is also justified because it has simple and defined steps to generate a standard of results that allows the comparison, reproduction and adaptation to various branches of production engineering, specifically those organizations that develop products and services (Dal Forno, 2012; Camp, 1989/2013; Womack and Jones, 1998).

A study by the magazine Fortune 1000 indicated that 65 percent of companies use benchmarking as a management tool to obtain competitive advantage (Anand and Kodali, 2008).

Thus, one of the forms of making companies more competitive is through the lean approach. Lean is an approach that seeks to eliminate "fat" or that is, all waste that can harm a system. The focus is on clients and the processes that add value in terms of price, schedule, quality and delivery, as well as social and environmental criteria (Mcmanus *et al.*, 2005).

The purpose of this paper is to describe benchmarking to evaluate the PDP from a lean perspective.

The benefits that the method can offer are increased business competitiveness through application of the continuous improvement and measurement processes, which motivate the reduction of time-to-market, improve the quality of the product, decrease development costs and deliver a product or service that the client wants.

Da Fonseca and Rozenfeld (2012) conducted a systematic review of the literature about product life cycle management, which encompasses the PDP. The authors

comment that the measurement of performance for this theme is a difficult and complex task, and that the units of analysis that were most found are references to the project. In this way, this study is supported by the need that companies have to possess indicators that guide them in the management systems.

This paper is organized as follows. Section 2 presents the research methodology. In Section 3 there is a review of the literature that was used to support the development of the method – performance evaluation, product development, lean and benchmarking. Section 4 presents the "BenchPDP_Lean" method and its application through multiple case studies at 12 companies in Brazil. The results are also presented and discussed (Section 5). Section 6 highlights the main conclusions achieved in this study and presents opportunities for further research on this topic. The references are listed at the end.

## 2. Research methodology

This work is part of the thesis by Dal Forno (2012), as can be seen in Figure 1. Nevertheless, the focus of this paper is to present the benchmarking method to diagnose how Lean is the PDP at companies. Thus, steps 4 and 5 are highlighted because they are the focus of this paper.

It should be remembered that the methodology is being described before the review of the literature is presented, while this was a support for formulating the methods, to both confirm that no indictors were found to measure the PDP scenarios in a quantitative form and to define the steps of the benchmarking method.

The samples from the applications of the case studies were defined based on the companies that responded to the survey, a random sample was conducted and the companies that were willing to participate and displayed interest in beginning to implement the lean approach in product development were contacted. The focus of this paper is not present a survey with large sample, but the detailed method and 12 applications in companies that develop products and are located in Brazil. The survey was previously applied and pre tested in companies to validated the method

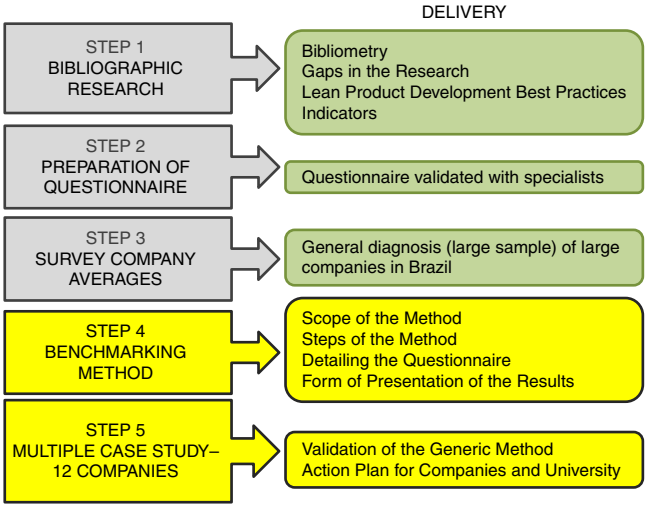



**Figure 1.**
Steps of the paper based on Dal Forno (2012)

and explore the dimensions and Method developed. One paper that contains this survey can be read in Dal Forno *et al.* (2013):

> The essence of a case study, the main trend in all types of case studies, is that it tries to clarify a decision or a set of decisions: the reason for which they were taken, how they were implemented and with what results (Yin, 2009).

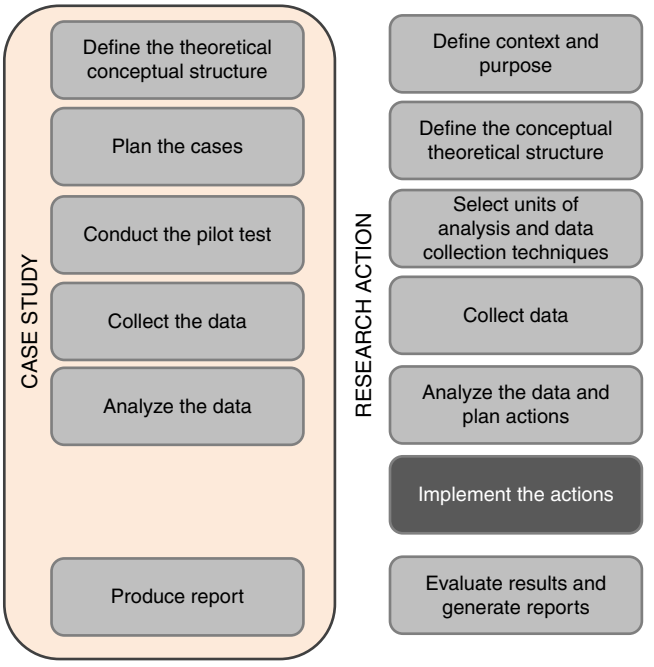
For Miguel (2010), the use of multiple case studies increases the external validity, although it does not allow generalization, but affirmations with less depth and it involves a greater consumption of resources.

This study treads along the very tenuous line between the case study and research-action methodologies. The border that it marks is that the actions suggested were not implemented at the units of analysis. Figure 2 distinguishes these two methodologies.

## 3. Review of the literature

The review of the literature seeks to unify the concepts of benchmarking with lean principles and practices, as well as the combination of the two, in the sense that benchmarking and lean are complementary.

This bibliographic study provided support for developing the five steps of the method – composition of the staff and choice of the project; questions about lean product development; analysis and presentation of the data; planning of the improvements; evaluation of the method and learning, for the eight dimensions of the questions (process, management, structure, people, product, client, supplier and waste); and for the questions of the detailed diagnosis in Section 4.




**Source:** Adapted by Miguel (2010)

**Figure 2.**
Difference between the case study and research-action

### 3.1 Benchmarking

Spendolini (1992), after collecting 49 definitions of benchmarking, created his own, based on a play on words: "a continuous and systematic process for evaluating products, services and work processes at organizations that are recognized as representatives of the best practices, with the goal of organizational improvement."

Explaining this concept, the idea of the process pre-supposes that as a method, benchmarking involves a continuous series of actions and steps that are related to the long term. The use of the word systematic or structured, signifies that there are support tools, such as flow charts, questionnaires and organized forms of collecting information. Through evaluation, understanding, measurement and comparison the understanding of value will be developed that will guide decision making, in a wide variety of areas, not limited to specific business processes. The benchmarking process involves an initial investigation to discover the names of the companies and what they do to be recognized as references in their sectors. The term world class applies to those companies that have the best practices. In terms of the size of the sample, or that is, it is necessary to choose organizations that represent the state of the art and the comparison needs to be understood as a guideline for orienting change.

One of the best known definitions of benchmarking dates from 1979, when the Xerox company began using the process to examine its unit manufacturing costs: "it is the continuous process of measurement of products, services and practices in relation to the strongest competitors, or to companies recognized as being leaders in their industries" (Camp, 1989/2013).

In sum, benchmarking identifies gaps in performance and opportunities for improvement, generally resulting in a change. Its proposal is to attain a sustainable competitive advantage, or that is, specifically, for a company to know itself. It involves studying the competing companies and the leaders, learning from them and being ready to adapt their best practices. This can be described as a structured process, with step-by-step models, providing a common language to organizations.

### 3.2 Lean

The five lean principles proposed by Womack and Jones (1998), originally thought of from the perspective of manufacturing, are easily adapted to the entire organization. These principles are:

(1) to specify and increase the cost of products from the perspective of the client;

(2) to identify the value chain for each product and remove the waste;

(3) to make the value flow through the chain;

(4) so that the client can drive production;

(5) management toward perfection.

The authors also mention that in manufacturing, a maximum of 5 percent of the activities add value. In administrative activities, the amount drops to only 1 percent for the flow of information.

Wastes are characterized as the elements of the processes that do not add value to the product or service, adding cost and time. In addition to the seven forms of waste existing in manufacturing (Ohno, 1988; Shingo, 1988) – over production, waiting, transportation, unnecessary processes, movement, defects and stock – in product

development there are three more forms of waste – reinvention, lack of discipline and lack of integration of information technology (IT). These forms of waste are symptoms and not the root cause of a problem, which reveals elements of the problem with the system in the processes and at the levels of the chain. Thus, the waste needs to be reduced and when possible eliminated.

It is important to understand the definition of each form of waste and the informational and behavioral aspects inherent to each one (Pessôa *et al.*, 2009; Bauch, 2004; Oppenheim *et al.*, 2011; Oehmen and Rebentisch, 2010):

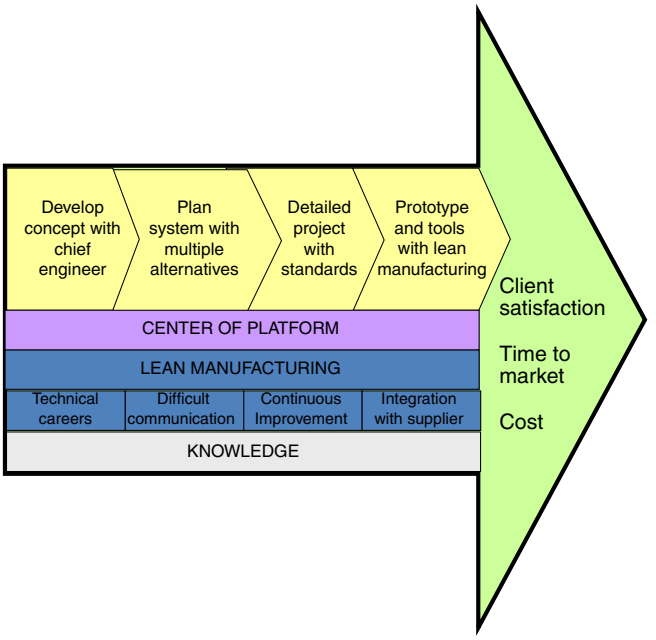
- Waste from over production characterized by producing more than necessary, or before solicited. Thus, as in manufacturing, in the PDP the concept is the same, that is, it is realized when there is an imbalance of processes. Examples of this waste are the excessive generation of information, documents and approvals, as well as redundant tasks.
- Waste from waiting occurs when the flow of value remains static, when people wait for something (information or a delayed delivery), when information waits for people (delivered much too soon) or when people wait for available capacity of resources (human or machines). The influential behavioral factors are the so-called non-returned and or delayed responses in the change of conditions.
- The aspects of transportation waste are related to the inefficient transmission of information, unnecessary traffic of data and information, transfer of responsibility between people or departments. Multi-tasking is also identified with this type of waste, because each time that a person needs to be reoriented to execute a task it is analogous to conducting a machine setup. In this way, promises are broken, there are weak abilities, obscure expectations and little or no feedback.
- Waste from unnecessary processes can be understood through non-optimized processes, which include activities or functions that do not add value, require excessive approvals, involve inappropriate use of competencies, tools or methods and many interactions.
- When people need to go somewhere to find data, access tools, try to resolve doubts or even seek information, whether in an electronic or manual media, waste from movement occurs. Its consequences are a crisis of management, turnover of people, repetition of errors and others.
- Waste from defects appear in the form of incorrect data or information in the specifications or functionalities of the product, deficiencies in the attributes of quality of information (accessibility, relevance, opportunity and ease of interpretation) and also include poor reviews, tests and verifications. Factors that accentuate this waste include a lack of knowledge, few suggestions for improvements, unsatisfied stakeholders and rushing.
- Waste from stock is seen in large quantities of heterogeneous information (large lots) that are waiting to be processed or to be liberated for the processes to follow. Other examples include: equipment and prototypes that are underutilized or even unnecessary, excessive data storage, delays along a critical route, high variability of the system, lack of control, old and obsolete information.

- Waste from reinvention can be understood as the low reuse of knowledge. Reinvention includes the failure to use existing solutions and experience acquired in previous developments, thus affecting the quality and efficiency of development. The waste comes from reinventing processes, solutions, methods and products that already exist or that only require a few modifications to become suitable to the problem at hand, or that is, poor reuse of engineering projects and the low reuse of knowledge.
- Discipline in the process includes basic factors that, if not observed, will cause a state of disorganization of work development such as: obscure goals and objectives, indiscipline in relation to planning, insufficient predisposition to cooperate, incompetence and poor training. Thus, waste from lack of discipline provokes the behavioral factors of informality, conflicts, individualism, deficient abilities and little or no feedback.
- A large variety of IT components (hardware, software, networks, etc.) and the challenge of being able to map the entire development process in an integrated manner that makes viable the use of current and future tools can lead to problems of incompatibility between software and hardware, an inability to meet requirements and specifications in terms of speed, reliability, ergonomics, updating and low availability. This is what composes waste from lack of IT integration.

Ballé and Ballé (2005) understand that lean development at Toyota is part of the company's entire system, the elements of which include process, organizations, practices (PDP tools and lean manufacturing) and culture. Thus, product development begins with the conceptual phase, led by the chief engineer. The system is then conceived using principles of set-based concurrent engineering (SBCE). The detailed project phase is conducted with the established project standards, the prototypes and tools with the principles of lean manufacturing, in addition to the participation of the supplier who was involved since the beginning of development and also the interactions with the internal and external clients to generate products of value. Figure 3 presents a schematization of the product development model at Toyota.

Kennedy *et al.* (2008) emphasize that the value flows for both product and knowledge need to be managed. The first concerns the flow of tasks, people and equipment that generate designs, bill of materials and the manufacturing process, desired by clients. Meanwhile, the other flow involves the capturing and reuse of knowledge about the market, client, technologies, products and production capacities, generalized with visual flows through projects and organizations.

This section defines the lean concepts focussed on principles and cites some practices that serve as support for the formulation of the questions in the "BenchPDP_Lean" method. Variability, which is highly present in product development, due to differences in times of arrival of tasks and of waste caused by inefficient engineering, which results in low levels of performance, can be reduced with lean practices. One of the ways is through the standardization of design, processes and competencies and also with SBCE, which integrates techniques of modularity, trade-offs, early supply involvement, and project library with the recording of lessons learned, visual methods, etc. However, existing studies do not offer indicators to quantify how lean is the PDP at companies. The authors that described this gap are Hoppmann *et al.* (2011), León and Farris (2011), Moffett *et al.* (2008), Haponava and Al-Jibouri (2010), Gurumurthy and Kodali (2009) and Hong *et al.* (2010).




**Source:** Ballé and Ballé (2005)

**Figure 3.**
Framework for lean product development at Toyota

*3.3 Lean and benchmarking: similarities*

The Lean approach and benchmarking are aligned in the sense that they have common objectives. To summarize, Table I presents some criteria and the focus of each one of the approaches.

Considering Table I and the review of the literature of lean product development and benchmarking, it is possible to summarize the common points between the two:

- Communication – interdepartmental relations, offering incentives to critical thinking and multidisciplinarity, with a common language;
- Continuous improvement – supported by Kaizen principles;
- Application of best practices – identification of processes, tools and principles used by companies that are global references;
- Value of knowledge – the recording of lessons learned and the exchange of information, in addition to the human abilities;
- Standardization – methods defined to avoid "reinventing the wheel," making things simple;
- Focus on clients needs – they are the interested parties who stimulate beginning the action, leading to competitive advantage;
- Valorization of people – participation of people as parts of the process, providing incentives to their ideas and suggestions, and making investments in their training.

Authors that have conducted studies of benchmarking works have identified 71 different steps, 13 of which they have in common. More than 60 methodologies were

| Criteria | Benchmarking | Lean |
|---|---|---|
| Objective | Organizational improvement<br>weak points are opportunities | Add value<br>Eliminate waste<br>Continuous flow |
| Vision of the problems | Adapt practices of companies recognized as leaders<br>Guidelines for steering changes<br>Visualizing through gaps in performance | Act on the root cause to eliminate problems<br>Opportunity for improvements<br>5 Whys method |
| Quality | Total quality<br>Quality control circles | Basic stability factor<br>Quality at the source (Pilar Heijunka) |
| Planning | PDCA | Kaizen<br>A3 Report |
| Management | Support from upper management<br>Strategic | Visual management<br>Involvement of all the people |
| Measurement | Performance indicators | Goals "Zero Defects" |
| Diagnosis | Questionnaire | Value stream mapping |
| Transformation | Continuous improvement<br>Gradual<br>Structured<br>Organized form of collecting data<br>Long term | Focus on people<br>Incremental<br>Do more with less<br>Standardization<br>Long term |
| Reference | Best practices | World class companies |
| Example | Xerox | Toyota |
| Statistic | Statistical control of process | Six sigma |
| Knowledge | Continuous learning process<br>Self-evaluation | Recording and using lessons learned<br>Valorization of employee ideas |
| Client driven | Stakeholder satisfaction | Identify client value |
| Type of application | Generic<br>Competitive<br>Internal<br>Functional<br>Strategic<br>Collaborative | Lean manufacturing<br>Lean design<br>Lean office<br>Lean service<br>Lean logistics<br>Lean healthcare |

**Table I.**
Points in common in lean and benchmarking

analyzed (Anand and Kodali, 2008; Anderson and Mcadam, 2004; Bhutta and Huq, 1999; Carpinetti and Mello, 2002; Christian-carter, 2002; Dattakumar and Jagadeesh, 2003; Deros *et al.*, 2006; Gonzalez *et al.*, 2008; Gurumurthy and Kodali, 2009; McAdam *et al.*, 2008; Moriarty and Smallman, 2009). Works with the keywords "Performance Evaluation" and "Lean Product Development" were also evaluated. From these crossings, the main studies found from the period from 2007-2012 were:

- Sharma and Kodali (2008) – this is an evaluation of 23 frameworks and indicators of world class manufacturing.
- Bhasin (2008) – affirms that less than 10 percent of organizations in the UK successfully implement lean practices. Thus, the author proposes a generic model of multi-dimensional performance dynamic supported by a balancescorecard. It cites problems of traditional metrics.
- Morgan (2007) – the author mentions four challenges to projecting supply chain management (SCM) indicators: lean/agile effect in the SCM; a need to develop measuring systems that break barriers; cultural barriers between countries; and

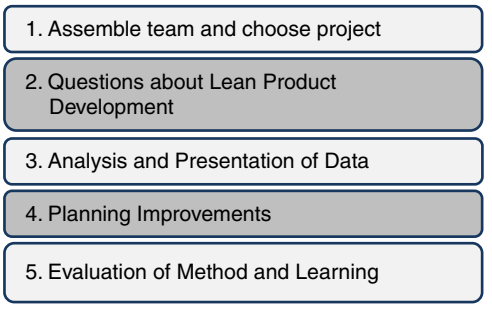
making the SCM more effective internationally. In addition, it alleged that the problem is that administrators do not treat the measuring system as a vehicle for organizational change.

- Allee (2009) – provides examples for evaluating the value of creation of networks and resolving organizational problems through a social network analysis.
- Lima *et al.* (2009) – these authors discuss the roles of the performance measuring system and among those found are that of generating positive changes in the organizational culture, providing better understanding of client needs, implementing functional strategic management and developing the ability for continuous improvement.
- Afonso *et al.* (2008) – applied a questionnaire at 500 companies in Germany that was divided into seven parts: general information; PDP; time-to-market; PDP indicators, target cost and commentaries.
- Gautam and Singh (2008) – in general, the authors evaluated through a case study at an automobile manufacturer the impacts of a change in product on adding value to the client from incremental projects. The study evaluated the levels of costs of changes in engineering, levels of perceived value, levels of complexity of the parts to be altered, costs of equipment, unit costs and the costs of providing guarantees, quality levels (trust, service and durability).
- Thus, to make the method developed clear and simple, the five steps are presented in Figure 4.

## 4. Multiple case studies of the "BenchPDP_Lean" method

This section will describe the steps of the "BenchPDP_Lean," method developed in the thesis by Dal Forno (2012), present the application of multiple case studies at 12 companies in Brazil and discuss the results.

As described in the previous sections, this method is a generic version of various existing benchmarking methods. It is designed to be simple and reproducible, and is composed of five steps – choice of staff and project, application of questions, presentation of results, planning of improvements and evaluation of the method. Each step from Figure 4 will be presented in detail below.




**Source:** Dal Forno (2012)

**Figure 4.**
Steps of the "BenchPDP_Lean" method

*4.1 Step 1 – choice of staff and project*

This initial step involves the formation of the multidisciplinary staff and the choice of a project as a reference, in addition to compiling data about the company.

After defining the sample of companies at which the method will be applied, the instructions were given to the person responsible for the interface between the university and the company. The instructions are as follows:

- each participant will receive the manual with the method and the questions;
- each question is accompanied by an explanation so that everyone's understanding of the concepts are at a similar level;
- the question is presented to the team;
- some examples are cited to clarify the question;
- each person responds to the question by choosing one of five options; and
- the team cites comments that can be recorded with the company's authorization.

For the characterization of the company data were requested such as the company name, location, number of factories, the person responsible for the relationship between the university and the company and the main products manufactured.

To choose the project it is necessary to define a project/product or family of products (preferably one that has taken place in the past two years and that has been complex), the length of the project in months, photos and complementary data, the position of the company in the supply chain (its point on the chain, whether it is the supplier of equipment and tools, a first level supplier, second level supplier, supplier of commodities, supplier of raw materials, supplier of technology, supplier of services), the types of projects developed by the company (radical/innovative, platform, derived/incremental, follow source), types of relationships (risk partnership, technology partnership, strategic partnership, co-developer, supplier of services, supplier of standard parts), and its production strategies (make to stock, assemble to order, make to order and/or engineering to order).

For the choice of the multidisciplinary team, it is suggested that there be at least one member from each of the following areas: engineering, PCP, production, marketing, quality, purchasing, process, lean, costs/financial, sales/commercial, logistics, supplier and also, if possible, the final client. This material was previously sent to the company so that it could also provide the name, position and e-mail of each team member.

*4.2 Step 2 – questions about lean development of products*

The objective of this step is to present the questions that will compose the diagnosis of the current state of the PDP. The questions are divided into eight categories – process, management, structure, people, products, client, supplier and waste (Figure 5).

A manual was prepared for the companies in the form of a presentation file and later the method evolved to an electronic spreadsheet format to facilitate its completion. Below will be explained the objective of each category and the corresponding questions. Each question was graded from 0-100, on a interval scale of 25 points. The first option is the most lean, continuing in decreasing order. There is also space for comments from the team. Because of space constraints, Table II summarizes the focus of each question.

Category A – process: the objective of this category is to evaluate the knowledge about the flow of the process, if it is standardized, if improvements are made, if the

information is being transformed at each phase of the activity, what are the documents used and to identify the value of the internal client.

Category B – management: this category aims to identify how the planning and control of the PDP is being conducted, verify which are the indicators used, how the strategic objectives are developed, the synchrony of the portfolio with the available resources, what is the percentage of time destined to the initial steps of the PDP, the alterations made in the schedule, if there is visual management, if checklists are used, the frequency of accompanying the project and other items to be administered.

Category C – organization: this category seeks to identify how the people are organized at the company to achieve the strategy.

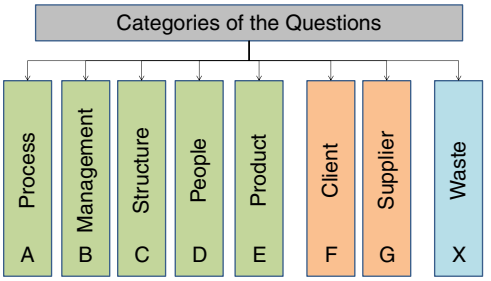



**Figure 5.**
Categories of the questions from the method

*A – Process*
- A1 Phases of the PDP and standardization of the process
- A2 Length of the phases
- A3 Delivery of the activities
- A4 Continuous flow, value of the internal client, quality of information, reference model for the PDP

*B – Management*
- B1 Development of the strategy
- B2 Risks
- B3 Change in schedule
- B4 Frequency of accompanying the project
- B5 Level of detail of the schedule
- B6 Planned × Realized
- B7 Portfolio management
- B8 Project Indicators

*C – Structure*
- C1 Organizational structure
- C2 Involvement of the departments
- C3 Communication between depts.
- C4 Project room

*D – People*
- D1 Stability of personnel
- D2 Project leader
- D3 Recording lessons learned
- D4 Abilities and Profile
- D5 Training

*E – Product*
- E1 Project for Product
- E2 Rationalization
- E3 Platform of Products

*F – Client*
- F1 Market strategy
- F2 Client needs
- F3 Client perception

*G – Supplier*
- G1 Degree of involvement of supplier
- G2 Joint definition of requirements
- G3 Structure of supplier

*X – Waste*
- X1 Over production
- X2 Waiting
- X3 Transport
- X4 Unnecessary processes
- X5 Movement
- X6 Defects
- X7 Stock
- X8 Reinvention
- X9 Lack of discipline
- X10 Integration of IT

**Table II.**
Questions of the method divided into categories

Category D – people: this category seeks to identify if there is turnover, what are the abilities of the staff, if there is staff training, what is the leadership style and the organizational structure.

Category E – product: this category seeks to identify if the product was projected to be easy to manufacture or assemble. The product reflects if the development was well planned, conceived and executed through the techniques (modularity, fast prototyping, standardization of materials, among others) which reduce the time-to-market and deliver value to the client.

Category F – client: this category seeks to identify how the company captures and incorporates the needs and the satisfaction of clients in the product life cycle (value from the point of view of the external client).

Category G – supplier: this category seeks to identify if the company is integrating the supplier(s) from the beginning of the PDP and what is the degree of partnership with the supplier.

Category X – waste: this category is considered a complement of the others, because it is the moment for the team to have the maturity to identify what are the forms of waste found in the PDP. Waste involves those elements of the process that do not add value to the product and were previously described (Bauch, 2004; Ward, 2007; Morgan and Liker, 2008). For each one of the ten forms of waste mentioned, comment where it occurs and cite examples of this waste at the company.

### *4.3 Step 3 – presentation of the results*

The objective of this step is to present the results of the application in graphic form. To do so, bar and radar graphs and the percentage of each category were used. In addition, for each application, a report was generated with comments in each question and the strong and weak points for each category. The graphs are presented in Section 4.2 with the multiple cases.

### *4.4 Step 4 – planning the improvements*

The objective of this step is to generate a plan of action with the improvements to be conducted. This step is conducted in conjunction with the participants. The detailing following the 5W2H model is optional as a function of the availability of the company and of the reliability of data. The A3 Report is used as a framework.

### *4.5 Step 5 – evaluation of the method*

The objective of this step is for the participants to evaluate if the "BenchPDP_Lean" method was useful to the company and if the questions were suitable. The five questions seek to evaluate the duration of the method; quantity of questions; the division of the categories; simplicity of the method and usefulness of the method for the company.

## 5. Application through multiple case studies

The purpose of this section is to describe and analyze the practical applications of the method conducted at 12 large companies in Brazil, given that seven of them are in the automotive industry, two in the electronics industry, one in the textile industry, one in metallurgy and one in capital goods.

Each application is described individually and also considering groups, implemented practice, categories and the evaluation of the method conducted by the participants. To maintain the privacy of each company, the names used here are fictitious.

The applications consist of multiple case studies, because even when there was participation from a researcher, she did not influence the results, but only clarified the concepts about the principles and practices of Lean Product Development and explained and applied the method, acting in an impartial manner.

According to Eisenhardt (1989) apud Miguel (2010), four to ten cases are sufficient in a multiple case study. In this work 12 studies were used of cases at Brazilian companies that develop products. The characterization of the applications is found in Table III. Table IV shows the characterization of the supply chain for each company, the segmentation of the projects and the existing relationships. Because of limited space, the names of the companies are indicated simply by letters from A-L.

## 6. Results and discussions

To illustrate, Table V shows an example of the applications with the strong and weak points of the company we will call "Towel."

Figure 6 shows an example of the scoring in percentage by category and by question. These amounts refer to the "Towel" company that clearly scored highest in the product (100 percent) and management (78 percent) categories, while people (30 percent), waste (0 percent), client (42 percent) and supplier (42 percent) are the categories with the greatest opportunities for improvements.

When comparing the scoring for each company, it was noted that Company G from the automotive sector attained a global level of 86 percent. Table VI shows that six companies are at the intermediary level, five at advanced and one at basic, indicating that no company is 100 or 0 percent lean. Many are seeking to apply lean product development in a systematic manner, but others have some isolated practices that are not part of a management system.

## 7. Conclusions

The method worked and met its objective, but it is important to remember that the application depends on people and even if a multidisciplinary team is participating, the veracity of the responses depends on the perception of each person responding and on the culture at the company.

| Fictitious name | | Sector | Product |
|---|---|---|---|
| A | Plastics | Automotive | Internal and external coverings for automobile doors |
| B | Fuel | Automotive | Fuel and suspension systems |
| C | Towels | Textiles | Bed, kitchen and bath (towels, bed linens) |
| D | Compressor | Capital goods | Air compressor |
| E | Stove | Electronics | Home appliances (refrigerators, freezers, clothes dryers and water purifiers) |
| F | Telephone | Electronics | Telephone exchanges, telephones and condominium exchanges |
| G | Motor | Automotive | Drive systems (Automotive motors and transmissions) |
| H | Forge | Automotive | Cast and milled auto parts |
| I | Machine | Automotive | Farm machinery and construction equipment |
| J | Pipe | Metallurgy | Seamless steel pipes |
| K | Suspension | Automotive | Fuel and suspension systems |
| L | Spring | Capital goods | Helicoid springs and stabilizing bars |

**Source:** Dal Forno (2012)

**Table III.**
Characterization of the 12 case studies

**Table IV.**
Characterization of the supply chain and projects of the companies

| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Position in the chain* | | | | | | | | | | | | |
| 1st level supplier | x | x | | | | | x | x | | x | x | x |
| Service supplier | | x | | | | | | | | | | |
| Tech. Supplier | | x | | | | | | | | | | |
| Equip. Supplier | | x | | x | | | | | | | | |
| Final consumer | | | x | | x | x | | | x | | | |
| *Type of project* | | | | | | | | | | | | |
| Radical | | 30 | 10 | 10 | 30 | 30 | 5 | | | 10 | 30 | |
| Platform | | 20 | 60 | 10 | 30 | 35 | 20 | 50 | | | 20 | 15 |
| Incremental | 98 | 30 | 30 | 70 | 40 | 35 | 15 | 50 | | | 30 | 85 |
| Follow-source | | 20 | | 10 | | | 60 | | 100 | 90 | 20 | |
| *Type of relationship* | | | | | | | | | | | | |
| Risk partnership | | x | x | x | x | x | | x | | | | |
| Technology partnership | x | x | x | | | x | | | x | x | x | |
| Strategic partnership | | | | | x | x | x | | | x | x | |
| Co-developer | x | x | x | x | x | x | x | x | | | x | x |
| Service Supplier | | x | x | | | x | x | x | | | | |
| Standard parts supplier | x | | x | | | x | x | | | | | |
| *Production strategy* | | | | | | | | | | | | |
| MTS | | | x | | | | x | | x | | | x |
| ATO | | | | | | | | | | | | |
| MTO | x | x | x | x | x | x | | x | | x | x | |
| ETO | | x | x | | | | | x | | | | |

**Note:** x, Signifies the presence of criteria
**Source:** Adapted from Dal Forno (2012)

| Strong points |
|---|
| *Process category* |
| A1 Phases of the PDP: the PDP and its phases have been evolving since August 2010, when the company began to formalize its model. At the time of application, the presentation is made and approval with management for compilation of 18 to 9 phases |
| A2 Length of the phases: at the time of application a schedule was presented with the phases of all the projects in parallel, with colors (beginning and ending dates) |
| A3 Flow of information: the flow of information is driven by the schedule at the level of phase, accompanying the checklist |
| A4 Rapid questions: from the perspective of the staff, the process flows continuously, there is a Reference Model for the PDP and it is being used in practice. In reality, the model was conceived and formalized based on the use in practice |
| *Category managment* |
| B1 Development of Strategy: the main reason for the company to launch a new product is to accompany market trends, in addition to substituting products that do not meet goals and to increase sales |
| B3 Alteration in the schedule: for the project evaluated and in the others, the release occurs on the scheduled date, but there are overtime hours (10-25% of the total project time) |
| B4 Frequency of accompanying the project: the meetings are multidisciplinary and occur weekly |
| B5 Level of detail of the schedule: the schedule is detailed by all involved in weekly meetings |
| B6 Overtime: 10-20% of the total project time is in overtime |
| B7 Portfolio management (resources): each manager assumes 3-6 projects, and the priorities are questioned at the meetings |
| B8 Project indicators: the indicators are used at each phase of the project and are updated weekly |
| *Category structure* |
| C3 Communication between departments: simultaneous development takes place with constant communication among some departments |
| *Category people* |
| D1 Stability of people: the rotation of people involved in the PDP is low (lower than 5% per year) a strong point at the company |
| *Category product* |
| E1 Project for the product: the project is well known and conceived, having been thought of during the project in reducing the number of components, reducing the time of production time (lead time) there is concern in designing the product to facilitate production, there are checklists of items to be verified, possible errors and problems with the product are foreseen and simulated and virtual simulations conducted |
| E2 Rationalization: there are all the alternatives available for rationalizing the product project – rationalization of raw materials, sizes/steps, components, packaging and for the reduction of setup. They are separated daily for reuse |
| E3 Platform of products: one of the platforms exists since 1980, that is, for more than 30 years. Thus, the company has the concept of a very strong platform |
| *Category client* |
| F1 Market strategy: know the clients' requirements well. The team commented that the position of the company in the chain allowed knowing the clients very well |
| F3 Perception of the client: the company has a structure of people and indicators to accompany the client in post sales for a long time because it wants to know that the product meets expectations and also evaluates the relationship of the client with the competitors products. This accompaniment is done mainly via SAC |
| *Category supplier* |
| G1 Degree of involvement of the supplier: the company involves a large part of the suppliers, one of which is strategic, (raw materials) |
| G2 Fast questions: most of the issues evaluated are strong |
| (*continued*) |

**Table V.**
Strong and weak points of the "Towel" company

G3 Organization of the supplier: the suppliers use modern work techniques, an important business for the supplier, suppliers of chemicals are certified, they have procedures to solve problems, deliver on time, they adapt to changes in relation to quantity, provide surplus parts at stable prices and can offer services and support with fast response

Weak points

*Category process*

A4 Rapid Questions: the quality of the information is not measured and the value of the internal client is not identified to improve the process

*Catgory management*

B2 Risks: the company does not have as a practice the management of risks, this is done at a macro level and without classifications

*Category structure*

C1 Organizational structure: the ideal is that the structure of innovative projects have a strong matrix, with the presence of a leader of the project throughout the project in a horizontal form, accompanying all the phases. Nevertheless, in the case of this company, there is a functional/departmental organization, independent of the type of project, given that this structure is more suitable for incremental projects which account for 30% at the company

C2 Involvement of the departments: the integration of the various areas from the beginning of the project is weak, given that in the early phases marketing is strongly present and the other departments are involved more in the development portion. At the launching, marketing and PGC are involved. It would be ideal to involve various departments from the beginning, but also balance the degree of involvement of each one, for example, logistics would have little involvement in the early phases and greater involvement in preparation for production

C4 Project room: there is not a specific space for the project to group the information and exhibit it in a visual manner. A more detailed analysis is needed to see if the company can exhibit the project information in a visual manner, given that the environment is often the same in which meetings are held with people from outside the company

*Category people*

D2 Project leader: this issue was not applied to the company, because there is no project leader

D3 Recording lessons learned: the company does not have this practice

D4 Abilities and Profile: there is only an analysis of abilities and profile for special projects, which represent 10%

D5 Training: the company estimates that it invests from 40-60 hours per employee per year in training. A more detailed analysis is needed to know the hours of training of the product development team, including informal training that are not registered

*Category product*

E1 Product project: of the 6 practices mentioned, 3 are cited in the strong points. Although checklists are not used to reduce defects between phases, to simulate errors and possible problems that can occur with the product, such as using FMEA, and when possible using virtual prototypes to reduce costs with samples and avoid waste of costs and reworking

*Category client*

F1 Market strategy: the company knows from 30 to 50% of the clients and segments by type of consumer (romantic, practical, modern, etc.). A more detailed analysis is needed to segment the clients

F2 Client needs: there is no procedure to capture the client needs

*Category supplier*

G1 Degree of involvement of the supplier: the company considers 100 suppliers, but does not set priorities for strategic issues. Some suppliers that have existed for more time are those that provide services for the catalog (photos, samples). For the others the priority is the price. Thus, only 20-30% of suppliers are involved in the PDP

G2 Rapid questions: the suppliers do not participate in development, or in changes to the product, or tests and company strategy. The staff commented that the company does not focus on having a partnership relation with suppliers, which are still not trusted in this sector

G3 Supplier structure: even with the organization of the supplier having strong points, the supplier does not participate in the reduction of product costs, does not have guaranteed quality, or have competence to act in different phases of the PDP and does not monitor client satisfaction

**Table V.**

**Source:** Dal Forno (2012)

BenchPDP_Lean

| A | PROCESS | 75% | |
|---|---|---|---|
| | | Question | Category |
| A1 | Phases of the PDP | 75% | 19% |
| A2 | Length of the Phases | 75% | 19% |
| A3 | Flow of Information | 100% | 25% |
| A4 | Rapid Questions | 50% | 13% |

| E | PRODUCT | 100% | |
|---|---|---|---|
| | | Question | Category |
| E1 | Product Project | 100% | 33% |
| E2 | Rationalization | 100% | 33% |
| E3 | Platform for the Products | 100% | 33% |

| C | STRUCTURE | 44% | |
|---|---|---|---|
| | | Question | Category |
| C1 | Organizational Structure | 25% | 6% |
| C2 | Involvement of the Departments | 25% | 6% |
| C3 | Communication between departments | 75% | 19% |
| C4 | Project Room | 50% | 13% |

| B | Management | 78% | |
|---|---|---|---|
| | | Question | Category |
| B1 | Development of the Strategy | 75% | 9% |
| B2 | Risks | 25% | 3% |
| B3 | Change in Schedule | 75% | 9% |
| B4 | Frequency of accompanying the project | 100% | 13% |
| B5 | Level of Detail of the schedule | 100% | 13% |
| B6 | Overtime | 75% | 9% |
| B7 | Management of resources | 75% | 9% |
| B8 | Project Indicators | 100% | 13% |

| F | CLIENT | 42% | |
|---|---|---|---|
| | | Question | Category |
| F1 | Market strategy | 25% | 8% |
| F2 | Client Needs | 0% | 0% |
| F3 | Perception of Client | 100% | 33% |

| G | SUPPLIER | 42% | |
|---|---|---|---|
| | | Question | Category |
| G1 | Involvement of Supplier | 25% | 8% |
| G2 | Rapid Questions | 25% | 8% |
| G3 | Organization of Supplier | 75% | 25% |

| D | PEOPLE | 30% | |
|---|---|---|---|
| | | Question | Category |
| D1 | Stability of People | 100% | 20% |
| D2 | Project Leader | 0% | 0% |
| D3 | Recording Lessons Learned | 0% | 0% |
| D4 | Abilities and Profile | 25% | 5% |
| D5 | Training | 25% | 5% |

| X | WASTE | 0% | |
|---|---|---|---|
| | | Question | Category |
| X1 | Overproduction | 0% | 0% |
| X2 | Waiting | 0% | 0% |
| X3 | Transportation | 0% | 0% |
| X4 | Unnecessary Processes | 0% | 0% |
| X5 | Movement | 0% | 0% |
| X6 | Defects | 0% | 0% |
| X7 | Stock | 0% | 0% |
| X8 | Reinvention | 0% | 0% |
| X9 | Lack of Discipline | 0% | 0% |
| X10 | Integration of IT | 0% | 0% |

**Figure 6.**
Scoring for each category in the method

**Table VI.**
Classification of the companies evaluated

| Area | | Company A | B | C | D | E | F | G | H | I | J | K | L | AVG |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Process | 38 | 56 | 63 | 56 | 100 | 38 | 81 | 69 | 88 | 6 | 94 | 63 | 63 |
| B | Management | 44 | 91 | 81 | 53 | 88 | 69 | 97 | 25 | 84 | 50 | 88 | 56 | 69 |
| C | Structure | 38 | 69 | 44 | 69 | 69 | 56 | 92 | 63 | 94 | 63 | 81 | 69 | 67 |
| D | Personnel | 50 | 80 | 30 | 40 | 70 | 40 | 75 | 20 | 80 | 75 | 80 | 60 | *58* |
| E | Product | 25 | 92 | 100 | 75 | 83 | 100 | 100 | 58 | 33 | 67 | 83 | 42 | **72** |
| F | Client | 92 | 83 | 42 | 33 | 100 | 58 | 92 | 42 | 100 | N/R | 83 | 67 | **72** |
| G | Supplier | 83 | 75 | 42 | 67 | 83 | 58 | 100 | 67 | 83 | N/R | 92 | 67 | **74** |
| X | Waste | 0 | 30 | 0 | 53 | 53 | 28 | 50 | 68 | 68 | N/R | 50 | 58 | *42* |
| Total | | *38* | 67 | *44* | 54 | 75 | 56 | **86** | 51 | 79 | 52 | **81** | 60 | 62 |

**Note:** Bold in line, total signifies the two most values and column AVG the bold also signifies the three most values

For the companies, the value of the method is in the diagnosis, and based on it, the opportunity to organize an action plan for implementing the Lean Approach to PDP. For academic research, the value of the method is that it can be repeated and is generic, and its contribution is the advantages of benchmarking and the creation of questions that evaluate how lean is the PDP in an organized manner and with proper theoretical foundation.

The main contribution of the study is a simple, useful and reproducible method that has a set of measurable indicators and graphic representation identifying the lean product development practices, as well as a structured guide to the implementation of improvements that allow companies from different sectors to be compared at a national level and also in the international market.

The method fulfilled its main objective, which was to diagnose in a measurable way the PDP and to also be generic, showing itself to be useful for various industrial sectors.

In relation to some tools, note that:

- Mapping of the value flow – in the survey realized by Dal Forno (2012), 44 percent of the companies affirmed that they use this tool in the PDP. However, when detailed in the method, it was found that in many cases the use of this tool was restricted to only measuring the lead time of development and the time of the process. Since the flow is of information, an important metric tool is thecomplete and accurate, which measures the quality of information, in terms of its completeness and precision. In the case studies, it was found that detailed mapping of the value flow is used only at four companies (stove, motor, machine and suspension), representing 33 percent.

- Standardization of the process – for the cases, all the companies have standardization of the process, with the exception of two that do not have a model and one affirmed that although it has a model, in practice it is not used.

- Initial involvement of the supplier – it was found that seven companies (58 percent) involve 70-100 percent of the strategic suppliers from the beginning of development. In relation to the number of suppliers, there is a large variation within a sector, which was from five to 215 suppliers being considered strategic.

- Voice of the consumer – in the cases, the category client sought to verify this in questions F1 and F2. Considering here a sample of 11 companies, eight companies (73 percent) responded that they know 85-100 percent of their clients and what they consider to be value. Meanwhile, in relation to the use of techniques for capturing VOC, four companies (36 percent) did not have any type of technique, three companies have one and always use it, and three companies use only some qualitative or quantitative analysis and one uses it for the main clients. Considering the average, the amount was 48 percent, which is intermediary. Thus, this practice that is based on the first lean principle – to know what is value for the client – reveals that there are still opportunities to be developed at the companies.

- Simultaneous engineering/integration – eight companies from the case studies (80 percent) involve various departments from the beginning of the process, and as suggested by Rozenfeld *et al.* (2006), Dekkers *et al.* (2013) and Lettice *et al.* (2010) areas such as project management, marketing and quality are important if they are more involved in the informational and conceptual design. The departments such as product and process engineering have greater involvement in the detailed project and in management of project, production and supplies are involved more in product

preparation. It is important to involve various areas, but it is necessary to balance this so that there is no waste and involvement without need, or then evaluate how much each area can really contribute to avoid errors in the product and to what degree everyone has a systemic vision. This question also allows participants to reflect on their operations and perceive that this field should be more involved or participate more actively from the beginning of the project.

- Product – the category product sought to evaluate if there are techniques for rationalization of the project, DFX or product platform. At three companies the product category scored 100 percent. These companies are at the point of the chain (Towel, Motor and Telephone). Four of the cases scored from 75-95 percent in the product category, two companies from 50-70 percent and three companies indicated that the product is a weak point.
- Value of internal client – eight companies demonstrated this concern (67 percent).
- Organizational structure – 50 percent of the companies have a weak matrical structure and 25 percent a balanced one which is appropriate for the types of project involved.
- Frequency of the accompaniment of the project – in the cases verified, at 50 percent of the companies the management meetings are weekly and the technical meetings are daily. At two companies (17 percent) the managerial meetings are bi-weekly and the technical meetings are weekly; at the remaining four companies (34 percent), there is no defined frequency for meetings or they are only of one type (technical or managerial).
- Virtual simulation – eight of the companies in the case studies have this practice (75 percent).
- Training – investing in staff training is important for stimulating continuous improvement and having a staff that is prepared to solve problems and design a product with greater value through a systemic vision The training, whether formal or informal, is an important element for evaluating the maturing of the staff and also concern for the category "people." In the case studies, considering the average, it was noted that both the question of training as well as the category of people had intermediary values. The data referring to the training were obtained through consultations with the HR departments at each company, which often does not have precise numbers or the data available groups all the company sectors. The category people remained at 58 percent and 60-80 hours of training per employee per year was dedicated. According to the Brazilian Association for Training and Development (Associação Brasileira de Treinamento e Desenvolvimento, 2006), Brazilian companies invested 47 hours of training per employee per year while US companies invested 30 and Europe 36.
- Scheduling delays/overtime – in the practical application (the case studies) for 58 percent of the companies there is a change in the schedule of 10-25 percent in relation to the initial forecast. However, there are projects that had defined dates for launching and even when there is a delay, there was overtime. The realization of 10-20 percent of overtime in relation to the total project time occurs at 75 percent of the companies (eight cases).

- Registration of the lessons learned – only four of the twelve companies (34 percent) make and use records in a complete form, while another 34 percent do not keep any type of records. In an intermediary line, there are two companies that only keep records, but do not use them in practice, which winds up compromising the efficiency of the practice and there are two other companies that do not use them for all projects.

Thus, given the diagnosis for evaluating the trends at Brazilian companies and with the more detailed practical application at 12 companies, it is possible to conclude that companies are beginning to introduce the lean approach for PDP although there is still potential for application of more practices and principles that need to occur in a planned and systematic manner.

It is important that the academic and business community continue to develop partnerships to make Brazil a more competitive country in the realm of product development, delivering products of value and with an increasingly shorter time-to-market.

It was possible to perceive that companies in Brazil are beginning to consider product development a strategic part of business, altering its profile as a country where companies use follow-source projects to that of a country where projects are developed, with characteristics adapted to the profile of the client and seeking lean management of processes.

The value of this work is revealed in the delivery of a structured method that allows evaluating if a company has a lean PDP. This evaluation is conducted with benchmarking, with well-defined steps and questions based on lean principles and practices on five levels. In this way, after the diagnosis, the company comes to know the strong and weak points and in this form prepares a plan of action to implement the needed improvements.

The study is of interest to people in the academic community because it provides a structured method that can be used in research and be expanded to other fields, such as services and logistics. It is also of interest to companies that can use the method presented in the study to evaluate their PDP in a simple and systematic way. The result is the method developed, which develops a classification for three levels of Lean Processes and Development – basic, intermediary and advanced (according to scoring on diagnostic questions) and the creation of eight categories – process, management, structure, people, product, client, supplier and waste).

Future works can be directed to apply this method in other countries and compared with Brazilian companies results.

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