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Practices for continuous improvement of the Product Development Process: a comparative analysis of multiple cases

Práticas para a melhoria contínua do Processo de Desenvolvimento de Produtos: análise comparativa de múltiplos casos

Fabiane Letícia Lizarelli[1]*
José Carlos de Toledo[1]

Abstract: The performance improvement of the Product Development Process (PDP) and other innovation processes is a recurrent concern in organizations. The results of these processes are critical to the competitiveness and long-term survival. One way to obtain better performance in these processes is the use of Continuous Improvement (CI) philosophy. The purpose of this article is to identify, through a literature review, the main practices for CI in the PDP and investigate the level of implementation of these practices in four innovative Brazilian companies which perform product development activities in the country and have structured CI programs. The results showed that there is still difficulty in implementing some improvement practices in the PDP, especially those related to the identification of barriers to implementation of CI, structuring improvement projects, and encouraging improvement actions in the PDP. Despite the difficulties, the implementation of practices for CI in the PDP has been identified as highly important for the companies studied.

Keywords: Continuous Improvement; Product Development Process; Continuous improvement practices.

Resumo: *A melhoria no desempenho dos processos de Inovação e de Desenvolvimento de Produtos é preocupação recorrente nas organizações. Os resultados desses processos são críticos para a competitividade e sobrevivência a longo prazo. Um meio para obter melhor desempenho nesses processos é o uso de abordagens de Melhoria Contínua (MC), comumente já aplicadas aos processos de manufatura, ao Processo de Desenvolvimento de Produto (PDP). O objetivo deste artigo é identificar, por meio de revisão bibliográfica, as principais práticas para MC no PDP e investigar o nível de implantação destas práticas em quatro empresas brasileiras consideradas inovadoras, que realizam atividades de desenvolvimento de produto no país e que possuem programas estruturados de MC. Os resultados encontrados mostraram que ainda há dificuldade de implantação de algumas práticas de melhoria no PDP, principalmente aquelas relacionadas à identificação de barreiras para implantação da MC, organização de projetos de melhoria e incentivo a ações de melhoria no PDP. Apesar da dificuldade, a implantação de práticas para MC no PDP foi identificada como de alta importância para as empresas estudadas.*

Palavras-chave: *Melhoria Contínua; Processo de Desenvolvimento de Produtos; Práticas de melhoria contínua.*

1 Introduction

In general there is a growing concern for improving the performance of the Product Development Process (PDP), since the introduction of new products to market is a critical factor for the competitiveness of the organization and its long-term survival (Lager, 2000; Sun et al., 2009; Yan & Makinde, 2009). For some authors it is very important to focus on improving manufacturing processes as PDP to become competitive (Clark & Fujimoto, 1991; Caffyn, 1997; Spivey et al., 1997; Nilsson-Witell et al., 2005). The effectiveness of the PDP can be as important for competitiveness as their own innovative products that may be released (Yan & Makinde, 2009).

According to Ettlie & Subramaniam (2004) there is a significant effort of academic research related to PDP management and improvement since the beginning of the 1990s. The PDP can be understood as a sequence of activities that firms undertake to

[1] Departamento de Engenharia de Produção, Universidade Federal de São Carlos – UFSCar, Rod. Washington Luís, SP-310, Km 235, CEP 13565-905, São Carlos, SP, Brazil, e-mail: fabiane@dep.ufscar.br; toledo@dep.ufscar.br

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design new products and place them on the market, encompassing the conception, project execution, manufacturing and marketing of the product (Ulrich & Eppinger, 1995; Rozenfeld et al., 2006; Unger & Eppinger, 2011; Tyagi et al., 2015). Other activities may also be part of the PDP, as a support for the production, release of the product, monitoring and the discontinuation of the product on the market, making the process even more complex (Cormican & O'Sullivan, 2004; Rozenfeld et al., 2006).

There is concern about the PDP improvement in order for it to be more efficient and effective without rework and waste of time in activities that do not add value to the process (Yan & Makinde, 2009; Yeh et al., 2010; Kowang & Rasli, 2011).

However, the quality programs such as, for example, TQM (Total Quality Management) or Lean, which could assist in improving the PDP, are still used mainly to improve manufacturing processes, even considering that these programs are suitable for the PDP (Caffyn, 1997; Sun et al., 2009; Sun & Zhao, 2010; Tyagi et al., 2015). Despite the diffusion of these and other Continuous Improvement programs (CI), little has been explored on the application of these programs and the concept of CI in the PDP (Caffyn, 1999; Nilsson-Witell et al., 2005; Sun & Zhao, 2010).

The CI can be understood as a set of activities that constitute a process of reasoning and intervention that seeks to achieve the improvement of the performance (Jha et al., 1996). It aims, through the involvement of employees, creating a sustainable improvement culture and eliminate waste in all systems and organizational processes (Bhuiyan et al., 2006). The CI is disseminated in the organization through programs, being the most used the TQM, Six Sigma, Lean principles and techniques for improvement and Lean-Sigma (Bhuiyan & Baghel, 2005; Drohomeretski et al., 2014; Kornfeld & Kara, 2011; Singh & Singh, 2015).

Unfortunately, the PDP is often excluded from CI programs due to the complex characteristics inherent to this process (Nilsson-Witell et al., 2005; Salgado et al., 2009; Sun & Zhao, 2010; Khan et al., 2013), such as the uncertainty and large volume of information and complexity of decisions involved. Rather than focusing on improving the PDP, many companies exclusively dedicate time and effort to improve the manufacturing processes (Ringen & Holtskog, 2011; Khan et al., 2013). And even companies that try to establish CI throughout the organization can be most successful in operational areas, instead áreas such as R&D (Caffyn, 1997).

CI programs should be expanded to include actions that improve the performance of the PDP (Nilsson-Witell et al., 2005; Chaudhuri, 2013; Tyagi et al., 2015). A well structured and managed PDP is a necessary condition to reduce the development time, managing risk and developing better products (Biazzo, 2009; Unger & Eppinger, 2011).

PDP's CI includes continuously identifying ways to increase the value generated by this process, reducing the costs of necessary activities, but that do not add value, and remove successively waste discovered on existing activities (Haque & James-Moore, 2004; Salgado et al., 2009). There is a lack of studies investigating the effects of CI programs within the product development context (Nilsson-Witell et al., 2005; Sun & Zhao, 2010). It is important to identify what principles and quality practices should be considered and included when starting a CI program in product development (Salgado et al., 2009; Khan, et al., 2013).

For the continuous improvement of the PDP can be applied principles of these programs, such as waste disposal (Chaudhuri, 2013) and tools such as, e.g., the Value Stream Mapping (Cooper, 2009; Sopelana et al., 2012; Tuli & Shankar, 2015; Tyagi et al., 2015), however, these and other tools and principles for the improvement of the PDP still remain little used and analyzed by the literature (Haque & James-Moore, 2004; Rossi et al., 2012; Tuli & Shankar, 2015).

The purpose of this paper is to identify, through literature review, the main practices for CI in the Product Development Process and investigate the level of implementation of these practices in four Brazilian companies considered innovative (with product innovation strategy), which conduct activities of product development in the country and have structured CI programs.

The identification of the main practices enables a reflection on how the CI actions can be effectively implemented in the PDP, viewing it as a process with waste, tasks that do not add value, repetitive or poorly executed, subject to improvements. The analysis of the implementation of these practices in companies makes it possible to know the degree of diffusion of CI actions in the PDP in organizations and what are the main difficulties encountered in the implementation, fostering academic and practical knowledge on the subject.

2 Theoretical Foundations

2.1 The Product Development Process

The PDP is inserted into a macro process, the Innovation Management, which involves processes such as: prospecting marketing and technological trends; generation and evaluation of ideas; building innovation strategy; management of resources and partnerships; the PDP; process of developing technologies and the process of innovation evaluation (Quadros, 2008). These are called processes of Research and Development and Innovation (R&D&I).

Innovation must be managed as a process through phases and routines, which is not restricted to R&D departments or Engineering (Tidd et al., 2008). This process consists of three phases: seeking opportunities and threats; selecting opportunities for development; and implementing the outcome in the market, the PDP implementation is embedded in the final stage (Tidd et al., 2008).

The PDP covers procedures and methods that companies use to design new products and make them available to the market (Unger & Eppinger, 2011). It can be understood as the sequence of steps and activities that a company employs to conceive, design and market a new product or improving an existing product (Ulrich & Eppinger, 1995).

There are several PDP models, they vary in the number of sub-processes or activities for the development, mostly they include: the concept generation; product design, that can be subdivided, e.g., in system design and detailed design; the preparation for production and launching the product on the market (Clark & Fujimoto; 1991; Wheelwright & Clark, 1992; Ulrich & Eppinger, 1995; Rozenfeld et al., 2006). There are PDP models that are flexible in prescribing activities, which seek to postpone the settings on the product design, to reduce the uncertainty of the decisions, and use overlapping stages, having great interaction between the upstream and the downstream activities of the process (Biazzo, 2009).

One of the best-known models for the PDP structure is the Stage-Gates proposed by Cooper (1990), which has stages of development and analysis steps for the continuation of the project. The challenges faced in using the Stage-Gates include governance and bureaucracy issues (Cooper, 2008), stiffness in the activities and extended deadlines for completion (Biazzo, 2009). Models used for the PDP, as the Stage-Gates can be inflexible and time-consuming, however, companies in dynamic markets require development speed and agility to changes during the PDP (Unger & Eppinger, 2011).

In response to these challenges can be used best practices in the PDP that can be seen as factors that facilitate and help in driving the process (Cormican & O'Sullivan, 2004; Barczak et al., 2009). Examples of good practice are: the use of structured and well defined processes (Ettlie & Elsenbach, 2007), cross-functional teams, interdepartmental work and collaboration of all functions in the PDP to anticipate the detection of problems and use practices for the management of projects (Rozenfeld et al., 2006; Tidd et al., 2008; Yeh et al., 2010).

One approach that supports collaboration is simultaneous engineering, where cross-functional teams assist in the integration of the functional areas involved in the development and between customers and suppliers (Rozenfeld et al., 2006; Tidd et al., 2008). Tools and techniques also support the actions needed in every step of the PDP. Some of these tools and techniques are the QFD (Quality Function Deployment), the FMEA (Failure Mode and Effects Analysis), the analysis of the life cycle, the DOE (Design of Experiment) and the Design for X, which may assist in the development of one or more steps of the PDP (Nijssen & Frambach, 2000; Thia et al., 2000; Yeh et al., 2010).

Recent approaches such as the Lean product development and the Design For Six Sigma (DFSS) have presented new visions for the PDP (Rozenfeld et al., 2006; Cooper, 2008). Both approaches emphasize creating value for customers, in order to reduce waste, process vulnerabilities, development time and increase the quality of the final product (Fouquet, 2007; Gremyr & Fouquet, 2012). The DFSS proposes a model based on standardized PDP stages and gates, focusing on the critical features for quality and use statistical tools for analysis and measurement of product and process to meet the specifications and tolerances (Fouquet, 2007; He et al., 2010; Gremyr & Fouquet, 2012).

The Lean Development approach is focused on improving the PDP, bringing CI principles of Lean program for the PDP with the aim of simplification and reduction of formalization of work, making the process more organic and enabling postponement of decisions about the product and opening for changes in development (Rozenfeld et al., 2006; Fouquet, 2007; Salgado et al., 2009). Even though there is a range of possible models, approaches and tools to the PDP, there are still gaps in the discussion of specific practices to improve this process.

2.2 Continuous Improvement in PDP

2.2.1 Continuous Improvement: concept and programs

The CI is seen as a set of activities that form a process of reasoning and intervention in problems to improve performance (Jha et al., 1996). It aims to create a sustainable improvement culture through the involvement of all participants of the organization in the elimination of waste activities of all organizational systems and processes, including the PDP (Caffyn, 1997; Bhuiyan et al., 2006).

For the application of CI in operation processes, various programs have been used as the TQM, the Lean and the Six Sigma. Improvement programs have specific objectives, tools and methods. The Six Sigma focuses on reducing variability, the Lean aims to improve the flow of processes and the TQM increases the level of satisfaction of internal and external customers, Lean-Sigma combines Lean philosophy and Six Sigma tools, aiming a rapid reduction of waste

and variations providing customer value (Hellsten & Klefsjö, 2000; Andersson et al., 2006; Bhuiyan & Baghel, 2005; Bhuiyan et al., 2006).

The programs are developed through CI activities, which are actions, projects and initiatives that enable the objectives and principles of the programs to be implemented (Bhuiyan & Baghel, 2005; Singh & Singh, 2015). The activities follow methods such as the PDCA and DMAIC, that aims systematizing the identification and measurement of problems, identify the causes, propose action plans, analyze and measure the results generated and standardize the actions taken (Savolainen & Haikonen, 2007; Näslund, 2008; Singh & Singh, 2015). The methods use tools so that decisions are made based on information, facts and data (Andersson et al., 2006; Bhuiyan & Baghel, 2005). A compilation of these characteristics for each program can be seen in Chart 1.

Even companies with successful results in manufacturing processes must continuously improve their performance, including improvements of R&D processes, as the PDP (Lager, 2000). Therefore, it is necessary that CI programs are expanded to include initiatives that improve the performance of the PDP (Spivey et al., 1997; Nilsson-Witell et al., 2005; Sun et al., 2009; Yan & Makinde, 2009).

2.2.2 CI programs in PDP

An organization can improve the quality, development time and cost of the PDP simultaneously, by reducing problems, waste and rework in development projects (Harter et al., 2000; Sun et al., 2009).

Tools and methods as PDCA can be used to shorten the time of product development cycle, but are not clear what the most adequate, which improvement results can be obtained with use and which CI initiatives can be used in more incisively way in the PDP (Griffin, 1993; Lodgaard & Aasland, 2011).

A better PDP can be obtained with the use of focused team to problem solving and CI (Kowang & Rasli, 2011), better definition and description of the development process itself (Lager, 2000) and the standardization and process optimization (Chaudhuri, 2013).

However, there are several reasons, such as the complexity of activities and the volume of information involved for people working in the PDP are resistant to standardization of procedures and the definition of CI (Ringen & Holtskog, 2011). It is argued also that each new project is a single process related to its goals, singularities and specificities (Ringen & Holtskog, 2011), which would hinder the standardization and improvement of this process. According to Ringen & Holtskog (2011) the excessive standardization generated by the CI could hinder the implementation of new developments, since for these authors the PDP would be a process with unspecific, unstable and experimental routine. In addition, being an intangible, interactive and long-term process, it is more difficult to define and measure its results and what is quality to the process, making it difficult to focus on the CI, but not unfeasible (Caffyn, 1997).

Yet, several authors argue that the application of CI in the PDP is not only possible, but necessary (Caffyn,

Chart 1. Main Features of the programs related to CI.

Program (Start)	Principles	Methods and tools	Authors
TQM (1950)	Making all are committed to quality and customer focus	PDCA, quality statistical tools (histogram, Pareto, control charts, flow chart, etc.), management tools (correlation, affinity and tree diagram, etc.), visual management and benchmarking	Murray & Chapman (2003), Bhuiyan et al. (2006), Andersson et al. (2006), Singh & Singh (2015)
Lean (1960)	Define what value; identify the value stream and eliminate waste and cost; making continuous flow of value; let the customer pull the process and the pursuit of perfection	5S, poka yoke, setup reduction, Single minute exchange of die (SMED), kaizen, JIT, kanban, Value Stream Map, Total productive maintenance (TPM), visual control graphics, standardization, quality statistical tools; etc.	Bhuiyan et al. (2006), Haque & James-Moore (2004), Andersson et al. (2006), Salgado et al. (2009)
Seis Sigma (1986)	Reducing the number of defects, waste, resource utilization and variability	DMAIC, statistical process control, SIPOC, process modeling, quality tools, statistical tools, analysis of variance, DOE, etc.	Banuelas & Antony (2002, 2003), Raisinghani et al. (2005), Bhuiyan et al. (2006), Andersson et al. (2006)
Lean-Sigma (2000)	Using the best practices of Lean Manufacturing and Six Sigma to increase market share	Lean and Six Sigma tools and methods	Bhuiyan et al. (2006), Andersson et al. (2006), Drohomeretski et al. (2014)

1997; Yan & Makinde, 2009; Chaudhuri, 2013), this application is promoted through improvement programs.

The application of TQM in an environment of product development and innovation has been reported with contradictory conclusions, ranging from beneficial, negative or no tangible results (Brennan, 2001; Song & Su, 2015; Fernandes et al., 2014). The implementation of TQM in the R&D area is more challenging than in productive areas, since all R&D people should be involved, there must be training and awareness of the need to improve the PDP and often, the principles associated with TQM are closer to productive area (Brennan, 2001; Prajogo & Hong, 2008).

Several studies have analyzed the impact of TQM and quality management practices, such as support of senior management, training, employee engagement, among others, on innovation performance, and obtained favorable results, that the TQM fosters product innovation (Martínez-Costa & Martínez-Lorente, 2008; Hung et al., 2011; Kim et al., 2012; Ooi et al., 2012). The PDP management can take ownership of TQM principles, getting development cycle time reduction, process optimization and improvement of product quality by simplifying the development process (Sun et al., 2009; Sun & Zhao, 2010; Song & Su, 2015). However, the philosophy of TQM and its tools applied to the PDP context has not been sufficiently studied (Sun et al., 2009; Sun & Zhao, 2010; Song & Su, 2015).

The Lean program proposes the simplification and reduction of formalization of the PDP (Haque & James-Moore, 2004; Cooper, 2009; Yan & Makinde, 2009; Sopelana et al., 2012). Improvements can be achieved through the application of Lean principles (Lean Thinking), related to the value stream identification, elimination of waste in PDP and the pursuit of perfection (Haque & James-Moore, 2004; Salgado et al., 2009; Khan et al., 2013; Tuli & Shankar, 2015). The elimination of waste in the PDP involves the identification of critical activities and where to focus attention and improvement efforts (Rossi et al., 2012).

Companies also have used the Value Stream Mapping and other lean manufacturing tools in the PDP in order to eliminate waste and inefficiencies and maximize the value of the product developed (Yan & Makinde, 2009; Cooper, 2009; Sopelana et al., 2012; Tuli & Shankar, 2015; Tyagi et al., 2015). The literature in this area also brings few details on how the Lean can be used to improve the PDP, since the focus is on improving traditional manufacturing processes (Haque & James-Moore, 2004; Rossi et al., 2012; Khan et al., 2013).

Six sigma may also be used as a program for systematically improving the PDP (Chaudhuri, 2013). The efficiency of this process can be improved by applying the method DMAIC to understand the impact of the organizational and processes variables in the design cycle time, in the development cost and in the product quality (Chaudhuri, 2013). However, these applications are still little explored in the literature.

For the PDP's CI can resort to various programs, which can operate in parallel, the application expands and adapts the principles, methods and tools of traditional models (Chart 1) to the PDP context (Nilsson-Witell et al., 2005).

2.2.3 Characteristics and Practices of the CI in the PDP

The importance of the PDP's CI is significant both for greater efficiency, and to consolidate a PDP based on the principles of learning and improvement (Yan & Makinde, 2009; Kowang & Rasli, 2011). When the project team fails, the focus should be on the root cause instead of the effect or even punishment. The focus should be on the CI and learning, rather than the culture of blame and fear (Cooper, 2009; Sun & Zhao, 2010).

The focus on lessons learned, in the storage and transfer of these knowledge to the project teams, seeking to achieve improvements continuously creates a conducive environment to the spread of knowledge, with the support of project leaders as facilitators (Kowang & Rasli, 2011; Ringen & Holtskog, 2011).

The CI principles are a set of assumptions on how to view the organization and its relationship with customers, competitors and suppliers. The CI principles vary according to the adopted CI program (Chart 1), but there are common points as the search for minimizing waste, errors, use of resources and time in search of increased customer satisfaction and financial results (Andersson et al., 2006), these were considered the basis of the CI principles in the PDP. Each principle is implemented by a set of practices, which are activities to translate principles into action and consequently to implement CI. The practices are in this turn supported by a variety of techniques and tools (Nilsson-Witell et al., 2005).

> "Practice" can be understood as "way to do" (Houaiss, 2015) or the mechanical exercise of some trade; routine (Michaelis, 2015). Therefore, the term practice can be understood as the way to do, the routine of exercising some activity. In this research, the practices are considered to be the habitual behaviors that contribute to the existence of CI in a product development environment.

For the CI to be deployed effectively, practices must stimulate cultural change for the CI (Yan & Makinde, 2009; Ringen & Holtskog, 2011) and the insertion of metrics to promote the proactive and

reactive improvement (Caffyn, 1997; Schulze et al., 2013; Rossi et al., 2012; Sopelana et al., 2012). These practices should be able to identify and eliminate waste continuously, basing decisions on measurement systems (Haque & James-Moore, 2004) and identifying the causes of problems (Cooper, 2009; Khan et al., 2013).

The application of the CI practices in the PDP has become a more important issue (Yan & Makinde, 2009). Many organizations use to the PDP the same practices for improving manufacturing processes (Caffyn, 1997). And there are few studies investigating what practices should be considered when starting a CI program in the PDP and what difficulties and impacts generated by its use (Yan & Makinde, 2009).

3 Research method

A literature review and a field research on the use of CI practices in PDP was held. The research steps are shown in Figure 1.

The procedure used to conduct the literature research was the Systematic Literature Review (SLR). SLR uses well-defined procedures to identify, analyze and interpret all available evidence related to a research question, in an unbiased manner, replicable and evidence-based (Tranfield et al., 2003; Levy & Ellis, 2006; Kitchenham & Charters, 2007).

The steps for the conduct of SLR are planning, execution and analysis (Biolchini et al., 2007). Planning is the development and validation of a protocol for the research, which involves defining the problem and the question of revision, defininition of the databases that will be used, the languages of the publications, the most appropriate keywords for the search and the criteria for inclusion and exclusion of the publication to SLR (Biolchini et al., 2007; Brereton et al., 2007). Execution puts into practice what was proposed in the planning and the analysis shows research results (Biolchini et al., 2007).

The question that directed the SLR: What practices can be used to enable the implementation of the CI approach in the PDP?

The electronic databases selected as research source were: Web of Science, Science Direct, Scopus and Engineering Village. These bases were chosen because they have large number of journals, conferences and articles of interest to the area of study and international scope in the research area.

The search considered the last 26 years of publication (1990-2015). The initial search was carried out by observing the title, abstract and keywords the following search key: ((*"continuous improvement"*) *AND*(*"product development"OR"innovation"*)). The word innovation was included because in certain contexts it is used as a synonym for development of new products.

Searches returned a large number of articles (Table 1) that were filtered, first by language, English articles were selected because it is the universally accepted language for writing scientific papers; Portuguese and Spanish, by allowing an investigation of literature from developing countries such as Brazil. A second filter was applied in relation to areas of knowledge relevant to the topic (business, management, operations research, engineering or similar), with this filter, distant work of the objective of the research were excluded. A third filter was related to the type of file, it was kept congress articles and journals. As a fourth filter were read the title and summary of the articles and the availability of the complete article was observed (in databases, in the search sites and through direct contact with authors) and, finally, the complete reading was made of the article. After verifying if the article helped to answer the research question, they were selected. Several articles were repeated in more than one database, and after considering 29 articles on the topic remained.

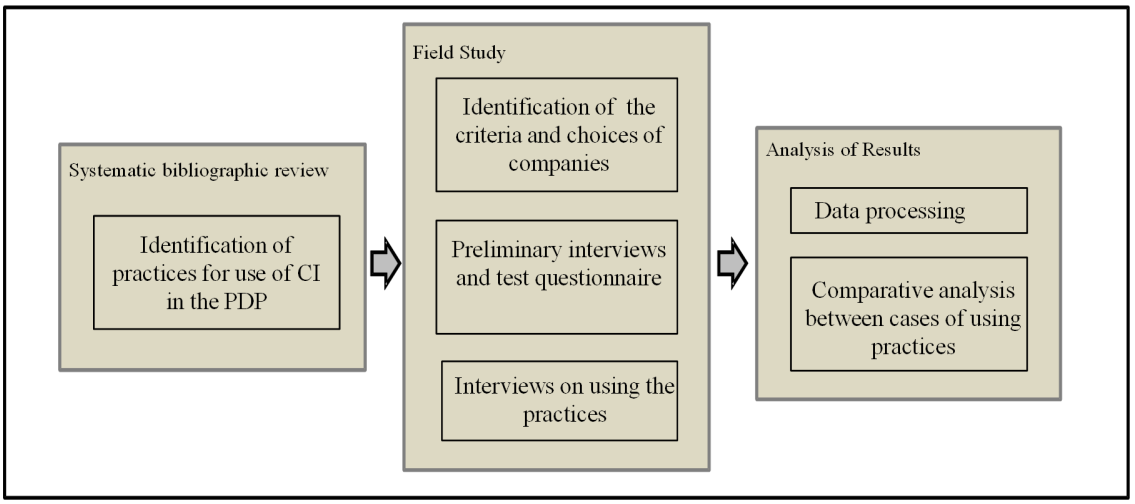

Figure 1. Research steps.

Upon completion of the SLR was also made a general search in Google Scholar and analysis of cross references, and included eight publications for review: Lager (2000), Brennan (2001), Haque & James-Moore (2004), Salgado et al. (2009), Chaudhuri (2013), Tuli & Shankar (2015), Song & Su (2015) and Tyagi et al. (2015). These publications were not found on the bases because they do not contain the search terms in the title, keywords or abstract.

Chart 2 presents the main authors who recommend the adoption of CI in PDP management. Some articles not directly cite the PDP, but present the approach of CI as important for the management of innovation or R&D, themes related to the PDP.

Practices were identified in the literature review that can be used for the implementation and support of the CI in the PDP. The practices were related to the PDP and other processes of innovation management, called the Research, Development and Innovation (R&D&I).

The practices were divided into two types: general practices applied for the implementation of CI, which can be extended to the PDP (Chart 3); and specific practices to the implementation and support of the CI in the PDP (Chart 4).

The second part consists of a qualitative approach of field research using the multiple case study method. The approach is qualitative because it seeks to draw the interpretation of individuals on the environment in which they work, through in-depht investigations and its context (Bryman, 1989). The case study is preferred in examining contemporary events, when the phenomenon can be studied in its natural environment (Yin, 1994), which is the purpose of the research. The advantage of analyzing multiple cases is that there is an increase in the external validity, helping to reduce the influences and tendencies of the observer and also reducing the risk of a false conclusion generated by a single event (Voss et al., 2002).

From the selection of cases, it was determined the techniques, both for the collection and for data analysis. Accordingly, it should be used multiple sources of evidence (Yin, 1994; Cauchick Miguel, 2010). Usually, the interviews, document analysis and observation are considered (Cauchick Miguel, 2010). The three sources were used.

To carry out field research, identifying companies where it would be possible to observe CI practices in the PDP context was required. The Companies to be studied should have the PDP and structured CI programs. To select companies with structured PDP were consulted about frequency of introducing new products to market and high financial returns with new products.

Table 1. Results in number of publications, to SLR.

Data Base	Initial search	Language filter	Area filter	Journal and conference papers	Complete papers
Engineering Village	208	202	196*	196	28
Web of Science	419	415	255**	245	31
Science Direct	70	70	43***	43	10
Scopus	901	882	756****	655	34

*Production Engineering; Management; Quality Assurance; Industrial Economics; Product Development; Industrial Engineering; Cost and Value; Production Planning; Manufacturing e Production Control. **Management; Operations Research; Engineering Industrial; Business; Engineering Multidisciplinary; Engineering Manufacturing; Public Administration and Economics. *** Business management and accouting; Economics; Engineering and Decision Sciences. **** Engineering; Business; Computer Science; Decision Science; Economics and Multidsiplinary.

Chart 2. Publications related to the use of CI in the PDP.

No. publicações	Autores de artigos relacionados ao uso da MC no PDP
37	Kocaoglu et al. (1991), Bessant et al. (1994), Caffyn (1997), Regan & Kleiner (1997), Bessant & Francis (1999), Lager (2000), Berg et al. (2001), Brennan (2001), Cole (2001), Sohal et al. (2003), Haque & James-Moore (2004), Nilsson-Witell et al. (2005), Middel et al. (2007), Cooper (2008), Cooper & Edgett (2008), Prajogo & Hong (2008), Cooper (2009), Sun et al. (2009), Yan & Makinde (2009), Salgado et al. (2009), Fàbregas-Fernández et al. (2010), Sandoval-Arzaga & Suárez-Barraza (2010), Sun & Zhao (2010), Furuhjelm et al. (2011), Rossi et al. (2011), Ringen & Holtskog (2011), Kowang & Rasli (2011), Lodgaard & Aasland (2011), Schulze et al. (2013), Yan & Makinde (2009), Chaudhuri (2013), Garcia-Sabater et al. (2012), Rossi et al. (2012), Sopelana et al. (2012), Khan et al. (2013), Song & Su (2015), Tyagi et al. (2015), Tuli & Shankar (2015)

Chart 3. General practices of CI identified in bibliographic review.

General practices that can be extended to the tmplementation of the CI in PDP	Authors
P1 - The company must create a CI culture, starting from the management level, with the creation of a set of behaviors and incentives to daily work that focus on the CI and allow it to be sustainable.	Caffyn (1997), Haque & James-Moore (2004), Nilsson-Witell et al. (2005), Sun & Zhao (2010), Ringen & Holtskog (2011), Schulze et al. (2013), Yan & Makinde (2009), Khan et al. (2013)
P2 - Improving communication. There should be regular communication with people involved in the PDP on the objectives and goals in order to identify CI needs and encourage participation.	Caffyn (1997), Yan & Makinde (2009)
P3 - Top management must continually provide training opportunities to update skills and knowledge in techniques and tools used in the CI.	Caffyn (1997), Ringen & Holtskog (2011), Yan & Makinde (2009)
P4 - Managers need to recognize possible blockades and barriers to implementation of CI. This will allow them to avoid wasting efforts on CI programs.	Yan & Makinde (2009)
P5 - Recognize and reward people for their efforts and actions related to the CI in all areas in the PDP or other R&D&I processes.	Caffyn (1997)

Chart 4. Specific practices for the PDP'S CI identified in bibliographic review.

Practices for deploying and sustaining the CI in PDP	Authors
P6 - The PDP managers or other R&D&I processes should understand what is CI and identify challenges when trying to extend the CI in PDP management. All of the PDP must understand the need for CI and the gains that can be obtained.	Caffyn (1997), Yan & Makinde (2009), Ringen & Holtskog (2011)
P7 - Senior management should invite CI deployment specialists and encourage people allocated to the PDP and/or R&D&I processes talk to the experts of companies that have well-established CI in PDP.	Caffyn (1997), Yan & Makinde (2009)
P8 - Use various improvement programs that focus on different issues, both in improving the product and improving the PDP, but they must be coordinated with regard to strategy, time, space and resources.	Nilsson-Witell et al. (2005)
P9 - Adopt the principles of quality and/or lean in PDP or other R&D&I processes and make people think about them and seek their effective implementation.	Haque & James-Moore (2004), Nilsson-Witell et al. (2005), Salgado et al. (2009), Rossi et al. (2012), Khan et al. (2013), Tuli & Shankar (2015)
P10 - Organize the CI as a separete process/project from the development projects management.	Caffyn (1997), Nilsson-Witell et al. (2005)
P11 - Prepare a report of unconformities on the PDP to suggestions for improvement and implement a database to capture best practices and lessons learned in the PDP.	Caffyn (1997), Rossi et al. (2011), Ringen & Holtskog (2011), Khan et al. (2013)
P12 - Using tools and techniques of the CI as the VSM (Value Stream Mapping) and other tools for process modeling, and quality management tools to identify and eliminate waste in the PDP.	Kocaoglu et al. (1991), Caffyn (1997), Haque & James-Moore (2004), Cooper (2008, 2009), Sun et al. (2009), Salgado et al. (2009), Sun & Zhao (2010), Yan & Makinde (2009), Schulze et al. (2013), Rossi et al. (2012), Sopelana et al. (2012), Tyagi et al. (2015)
P13 - Analyze the causes of problems in the PDP.	Cooper (2008, 2009), Khan et al. (2013)
P14 - Do not blame the PDP team when problems occur.	Cooper (2008, 2009), Sun & Zhao (2010)
P15 - Apply PDP performance metrics to identify improvement opportunities and implement them.	Regan & Kleiner (1997), Haque & James-Moore (2004), Cooper (2008, 2009), Ringen & Holtskog (2011), Schulze et al. (2013), Rossi et al. (2012), Sopelana et al. (2012)

The second criterion is related to the use of structured CI programs. This was the most difficult criterion to identify even consulting the website of the company and management reports available, it could not find information on the use of improvement programs in many organizations. Were selected four companies that present information in its institutional history about maturity in the use of CI and that allowed the study to be conducted. The selected companies belong to different industrial sectors, which enables a wider investigation into the use of practices in different contexts.

For the implementation of field research, it was developed a semi-structured questionnaire on the use of the identified practices. The first contact with the organization was made by telephone to identify the person responsible for PDP, it was sent, by email, a brief explanation of the research, and this person in charge was the bridge to the identification of research participants, including the ones from the CI area. It was attempted to select specific people in the company for the interviews: the development product projects leaders, the PDP managers and leaders or participants from CI programs. Preliminary interviews were conducted with three respondents (one from each of the companies A, B and C) as a basis for analysis and validation of the questionnaire and to refine the list of practices, with the inclusion of practices that were not found in literature. In the last stage of field research were conducted final interviews, with respondents in the preliminary stages and other respondents from each company. In this final step interviews were conducted in four companies (A, B, C and D).

For the analysis of results, a comparative analysis was performed between the cases, which made it possible to identify similarities and differences in the presence of the practices. This analysis was based on the opinions and statements of respondents about the level of use of each practice. The classification was adopted in levels (high, medium, low and unused) regarding the use and presence of practices. As there was more than one respondent in each of the companies, the analysis of the responses was made by the mode of the views of respondents, i.e. the level that repeats more among respondents. When there were two modes, qualitative interviews about the justification of the responses were considered. Chart 5 shows respondents per company and if they are related to the PDP, CI or both.

Chart 5. Interviewed per companies.

Company	Respondents
A	Manager of lean manufacturing (CI) Technical service laboratory manager (PDP) Technical specialist 1 and Black Belt (PDP and CI) Technical specialist 2 and Black Belt (PDP and CI) Black Belt manufacturing involved in PDP (PDP and CI)
B	Coordinator of product quality projects (CI) Product development senior manager (PDP) Process engineer and Black Belt (PDP AND CI) Manager of development projects (PDP)
C	Excellence in innovation manager (CI) Process and development senior engineer (PDP) Operational excellence project manager (PDP and CI) Senior researcher of R&D (PDP)
D	Manager of innovation projects (PDP) Manufacturing process and ci coordinator (CI) Process engineer (PDP AND CI) Technology engineer (PDP)

4 Field research

4.1 Cases

The chosen companies are considered references in innovation performance in Brazil and they are among the companies with the highest number of patents and new products launched. They are also quality product references and billing in their industries, being the leader or vice leader in Brazil in relation to the number of products sold in their respective market segments. Chart 6 presents an overview of the companies studied.

Regarding the collection of data, tools and sources can be seen in Chart 7. Each of the interviews lasted about two hours, but it should be noted that other contacts were made with each respondent, in person, by email or phone.

4.1.1 Company A

CI is widespread in the company with both the Six Sigma program support, as the Lean philosophy. Regarding the Lean, the company has developed projects in the supervising, coordination, engineering, management and operation levels linked to manufacturing. Concerning the Six Sigma, in Brazil, the company has a Master Black Belt (MBB) and 21 Black Belts in action, and a significant number of Green Belts (around 1200), both Black as the Green Belts work in various areas of the organization, including manufacturing, logistics, R&D, among others. This shows that CI has great dispersion in the organization and is not limited to a specific area or department.

Chart 6. General vision of the companies studied.

Characteristics	Company A	Company B	Company C	Company D
Capital	Multinational	Multinational	Multinational	National
Sector	Consumer goods	Home appliances	Chemical	Cosmetic
Size	Large	Large	Large	Large
Number of employees (Brazil)	4000	14000	2500	5000
Number of employees in R&D in Brazil	170	700	100	250
Annual revenues (Brazil-2013)	$1.2 billion	$3 billion	$1.2 billion	$2.5 billion
Average annual investment in innovative activities	5% to 7% of revenues	$ 100 million a year in Brazil	$ 50 million a year in Brazil	2.9% of revenues
% Of sales from new products	32% of the revenue from products with less than five years	25% of sales from products with less than five years	25% of sales from products less than five years	65% of sales are for products with less than 2 years

Chart 7. Summary of the data collection carried out in companies.

Instrument	Company A	Company B	Company C	Company D
Direct observation	Two visits to the R&D Laboratory and the productive area	A visit to the R&D division and the production area	Visits to the central unit, the production area and other to the R&D Center	A visit to the company in development and improvement of products areas
Interviews	**5**	**4**	**4**	**4**
Other instruments / observation means	Participation in lectures and workshops, exchange of e-mails and telephone conversations. Access to documentation of innovation project management.	Exchange of e-mails and telephone conversations. Access to documentation of innovation project management.	E-mail exchanges and telephone conversations to complement data and answer questions.	Contact by e-mails and telephone conversations to complement data and answer questions.

The company presents the PDP structured in stages and gates, based on the Stage-Gate model and on the concept of DFSS. The technicians and researchers from the Technical Service Laboratory (R&D division of the company) are trained at least as Green Belts, to achieve greater ease in applying the DFSS tools and techniques. Although researchers and technicians are trained as Green or Black Belts, and Six Sigma area assists the development projects of new products, knowledge is used to develop the product via DFSS and not to improve the PDP. There is no formal structure of application of CI in the PDP, there are ad hoc initiatives in order to reduce unnecessary steps, development time and PDP waste. The main improvement initiatives are related to the better definition of what is required at each stage or PDP activitie, as well as better instructions for completing the Project Charter and defining responsibilities.

Quantitative indicators to evaluate the PDP and research processes of new technologies are used. The main ones are: submission indicators of technical publications (information sent to the headquarters to determine whether a local or global patent or industrial secret must be generated), number of developments of new applications of existing materials, number of patents and percentage of revenues from sales of products with less than five years of release. Thus, there is a concern with the metrics of R&D&I processes, but there is no improvement goals of these processes.

There is no use of tools and techniques of the CI in more general processes of R&D&I, e.g., in prospecting processes of new technologies, strategic innovation management or even in the staff mobilization process for innovation in the company.

4.1.2 Company B

Regarding the CI, the company mainly uses the Six Sigma since 1997. It has a Master Black Belt who coordinates the Six Sigma hierarchy, more than 150 Black Belts employees and a great part of the manufacturing and R&D laborforce area is qualified as Green Belt. Six Sigma is applied in projects to improve processes, products or reducing variability and costs. The company uses also the Lean philosophy as a support to the CI since 2003 and recently Lean Sigma. Lean projects are more focused on productivity issues, setup time, stock in process, processes management and security layout.

The company has indicators for the PDP performance, some financial and billing rate of innovative products, new projects earnings indicators (real x expected); and some more general, such as development time. These indicators are quarterly evaluated and presented at meetings with general managers. The indicators used in the analysis assist the general performance of the PDP, but they are not specific for the identification of problems and enable the use of CI to the structured PDP.

Although almost all employees of the center of R&D are Green or Black Belts, there is no use of methods such as DMAIC, tools and techniques to improve the PDP's CI. The culture of CI is disseminated by the organization by the intensive use of Six Sigma, nevertheless, there is still no teams related exclusively to the PDP's CI or other innovation management processes projects. Improvements occur in a sporadically, led, when necessary, by the innovation manager. In this sense, it was made an initial mapping of processes related to innovation management processes, for understanding and improvement initiatives.

Respondents said to consider high the importance of carrying out structured actions in the PDP's CI and to perform specific actions for this purpose. Respondents considered medium the importance of using tools and CI practices in other R&D&I processes because of some of these processes, such as research of new technologies, having a nonlinear and complex nature.

4.1.3 Company C

Regarding the CI, the company has an Operational Excellence subdivision which is structurally positioned in the industrial department. This area of excellence assists in managing and improvement projects such as, the Six Sigma, *Kaizen*, Lean Sigma and TPM. The company has significant experience in CI projects for over 25 years and disseminate the tools and methods through training for the entire organization.

It also has an Innovation Excellence area, which aims to improve the practices and processes of innovation management. This area is responsible for identifying and standardizing the best practices for all types of innovation projects for all business units. It aims to identify and improve disabled points of innovation management and of PDP.

The best practices are disseminated through its standardization in the development of the projects. For progressing and validation of the gates is necessary the project to keep up with standardized information about tools used, schedule, financial data, among others. The data are stored in a system that helps to manage the key performance indicators. It is also encouraged as good practice that the lessons and the errors must be included in the reports, so that they are not to be repeated in future projects.

Some of the key indicators for PDP monitoring are: contribution margin analysis predicted and obtained by new development product projects, percentage of projects with high financial returns, number of projects in arrears and percentage of sales of products under five years.

In order to improve the PDP management were conducted Six Sigma projects using the DMAIC method and CI tools. It was identified several improvement actions such as better training on the role of leaders and project managers, seeking greater commitment; inclusion of project control system as required and subjected to the Quality System audits; besides recycling intended for project leaders in major tools that help the PDP, among others.

Indicators are used to control the improvement effects and identification of opportunities for improvements. The computer system helps in generating reports accompanying the PDP steps and the indicators, sent to each unit by the area of excellence.

The new product development and application materials projects are initiating the use of practices such as the formation of the improvement team to the research process of new technologies and materials, with the use of people from other areas to solve problems. The DMAIC tools are also used to solve specific problems in major innovation projects.

According to respondents, the use of CI practices and tools in the R&D&I processes, except for the PDP, is present in low grade. They are still specific initiatives, but considered important by respondents.

The use of CI practices is encouraged through training of innovation projects managers in tools and methods of CI and there is a disclosure of working tools and practices in the area of R&D.

4.1.4 Company D

Regarding the CI, the company began working with the establishment of semi-autonomous cells in 2006, along with *Kaizen* and TPM initiatives. The training extended to all persons connected to

the industrial area. In 2009, the company began to implement Six Sigma and from 2011 the Lean-Sigma. The improvement teams related to these programs are allocated under the responsibility of industrial management.

The company has performance metrics for the research area, e.g., the number of patents. For the PDP, indicators are used, as the percentage of revenues from products with less than two years of launch, the number of new releases per year and rate of return of each project. The initial return of new releases is important because the major product sales rate occurs in its release. Therefore, the company has focused on projects with significant commercial potential, which is evaluated on specific metrics.

There is also the company's concern with the identification and use of best practices for the development of new products. Despite this concern and use of performance indicators, there are no specific projects or actions for improvement for the PDP management.

There was no migration tools, methods and techniques of the CI for the technology area (Research area of the company). Respondents considered low the importance of this use for innovation area projects and actions, they considered an area with complex activities and in the company culture there is an association between CI and standardization, ie, it is considered that the CI is conflicting with the processes related to innovation management.

4.2 Analysis of the results

The first analysis in the field research was about the use and importance of the CI in the PDP and in other R&D&I processes. This first analysis was a general question about the use and importance, without delving into the details of each of the practices. The found level (zero, low, medium or high) of importance reflects the mode of the views of respondents. This criterion is also considered for all questions and further analysis.

Only Company C presents projects and structured actions of CI for PDP management and tools and CI practices in other R&D&I processes. Companies A and B have little structured use of CI in the PDP. Despite the lack of use in the D company, it was asked to all respondents if the use was considered of low, medium or high importance. The most frequent opinion in all companies is that the importance of using the CI in the PDP is high, even if such use is not yet being implemented in a structured way. Regarding the use of programs, tools and CI methods for other R&D&I processes it is not considered of high importance for three of the analyzed companies (A, B and D), and among the reasons is the complexity of processes involving research activities or other processes related to innovation management. This information is consolidated in Chart 8.

It is perceived that there are, among the respondents, a culture of seeing the PDP as a process amenable to improvement, measurement, dissemination of best practices, among other actions related to CI, but this perspective is still far from other R&D&I processes.

The second part of field research sought to identify the intensity of the use of practices for CI in the PDP and the other R&D&I processes (Chart 9). The chart with the opinion of each respondent for each practice (intensity: null - 0, low - 1, medium - 2 or high - 3) is in the Appendix A, as well as information of central position measurements and dispersion of data, for best compiling and analyzing the views collected in each company.

In the comparative analysis is noticeable that the company C has a differential, it has use of greater number of practices and more intense level of use of

Chart 8. CI utilization in the management of the PDP and other R & D & I processes.

CI use	Company			
	A	**B**	**C**	**D**
Use of CI in the PDP management	-Present, but unstructured - High importance - The company seeks greater structuring of the development process.	- Present, but unstructured -High importance -The company has no specific improvement actions.	- Present -High importance -There are assessment initiatives and improvement in PDP.	- Absent -High importance -The company has no specific improvement actions.
Use of CI programs, tools or methods in other R&D&I processes	-Absent -Medium importance for processes involving Research	-Absent -Medium importance	-Present -High importance -The Company uses in low-grade CI tools and practices in other R&D&I processes.	-Absent -Low importance

Chart 9. CI utilization in the management of the PDP and other R&D&I processes.

Practices	Company A	Company B	Company C	Company D
P1	Low use. There is the dissemination of the need of CI, but there are still no effective actions for their achievement in the PDP and other R&D&I processes.	Low use. There are only ad hoc actions of improvements, but there is no systematization of the actions.	Medium use. The company proposes CI projects and actions in the PDP and other R&D&I processes with an incentive to project managers and employees in the area.	Not used. The company also believes that the CI actions are focused on operational processes.
P2	Medium use. There is communication with those involved in the PDP of the main problems that need to be improved.	Medium use. There is communication of the main problems that need to be improved in forums and committees.	Medium use. There is communication of the main problems that need to be improved.	Low use. Communication is an important factor for the company, but there is no communication on identifying and solving problems in the PDP.
P3	High use. The Six Sigma program is widespread and there is also training consistency to the team of technical area.	High use. The Six Sigma program is widespread and there is constant training and members of the R&D team who are Belts.	High use. There is a concern with the CI and management excellence, with periodic training of R&D staff.	Low use. There are few training opportunities about CI and these are very general.
P4	Not used.	Not used.	Not used.	Not used.
P5	Not used.	Not used.	Not used.	Not used.
P6	Low use. All people are trained in principles of Six Sigma program, including managers. There is understanding of the program and benefits, but there is still no action to extend it effectively to the PDP.	Low use. All people are trained in principles of Six Sigma program, including managers. There is understanding of the program and benefits, but there is still no action to extend it effectively to the PDP.	High use. Project managers are trained in CI tools and try to extend the application to the PDP through an area of excellence in innovation	Not used. The company also believes that CI actions are focused on operational processes.
P7	Not used.	Not used.	Not used.	Not used.
P8	Medium use. It is used more than one program, but the focus on improving the PDP is not yet structured.	Medium use. It is used more than one program, but the focus on improving the PDP is not yet structured.	Medium use. It is used more than one program, but there is no coordination of efforts.	Medium use. It is used more than one program, but the focus on improving the PDP is not yet structured.
P9	Low use. The principles of quality are spread mainly by Six Sigma.	Low use. The principles of quality are spread mainly by Six Sigma.	Medium use. The principles of quality are widespread and there is a concern that people related to R&D&I apply them.	Not used.
P10	Not used.	Not used.	Low use. The first CI projects begin to be structured and executed.	Not used.
P11	Medium use. There is a database of best practices, but there are no reports of non-compliance.	Medium use. There are analysis and identification of best practices.	High use. There are documents and standards for the dissemination of good practices in database for all projects and reports on suggestions for improvements.	Low use. There are procedures of good practices.

Chart 9. Continuação...

Practices	Company A	Company B	Company C	Company D
P12	Low use. There is early mapping and modeling of processes.	Low use. There is mapping and modeling of processes.	Medium use. Using Six Sigma projects to improve the PDP and in some business units use the VSM in PDP.	Low use. There is mapping and modeling processes.
P13	Not used.	Not used.	Low use. No specific procedures.	Not used.
P14	Medium use. The problems are discussed at meetings to try to identify solutions.	Low use.	Medium use. The problems occurring in projects are discussed in project team meetings. The focus of these discussions is to find the cause of the problem and create documents and reports so do not occur in future projects.	Low use.
P15	Low use. Apply metrics, but not with the purpose of feedback to make CI.	Low use. Apply metrics, but not with the intention of performing CI.	Medium use. Indicators such as runtime, expected financial return and accuracy obtained are used to identify areas for improvement.	Low use. Metrics are applied, but not with the intention of having feedback to perform CI.

each. A possible explanation is that the company C has an area of Excellence in Innovation, which works to ensure standardization, the use of best practices and continuous improvement of the PDP and the other R&D&I processes, which is already in operation for around 7 years. Respondents emphasize that the excellence area promotes training in CI methods and tools, sets goals and monitors the managers involved in the PDP and other R&D&I processes, for them to perform CI activities. The company also offers improvement groups for new technologies and materials research process, as mentioned previously, using people from other business units to assist in solving problems in PDP and use of Six Sigma to CI and problem solving within Innovation Management processes, including the PDP. The company considers of high importance the use of CI in PDP and other R&D&I processes. This view of importance was given mainly by its achievements with the PDP's CI and the dissemination of concepts of CI by the excellence area.

Companies A and B have a similar level of implementation of the practices (médium), while Company D has a low level of implementation of CI. Respondents of company D consider that the use of CI in the PDP or other R&D&I processes are currently absent. Respondents from companies A and B, mostly considered that there is a concern with the CI mainly to the PDP, however, there is still no proper structure for its implementation, mainly because although they are companies with great innovative potential still face mapping and structuring of R&D&I processes issues, including the PDP.

The analysis of field research results made it possible to observe the level of implementation practices of the cases studied. The overall analysis of each practice can be seen in Chart 10.

Practices with lower utilization rates are "Managers need to recognize possible blockades and barriers to implementation of CI" (P4), "Recognize and reward people for their efforts and actions related to CI" (P5), "Senior management should invite the CI deployment specialists" (P7) and "Organizing the CI as a process/projct separate from the development projects management" (P10).

Both pratices P4 and P5 show the difficulty of structuring the CI for R&D&I processes and for the PDP, although the companies have more than one deployed improvement program. The absence of P7 and P10 practices shows that companies still do not use in the PDP environment the same CI deployment mechanisms that are adopted in manufacturing process environments, with also no concern and no systematic way to "Analyze the causes of problems in PDP" (P13).

The analysis also enabled the identification of practices in greater use, "Top management must continually provide training opportunities in CI" (P3),

Chart 10. Analysis of use of practices in the companies studied.

Practices	Analysis of the use of practices
P1	Companies find difficulties in this practice to effective actions on the management side encouraging CI and a systematic use.
P2	The practice of communication is being implemented so that the people involved know the main problems to improve, but there is still no stipulation of goals and improvement objectives in PDP or other R&D&I processes.
P3	This is the practice more used by companies interviewed, three of them have high utilization, two companies maintain a periodicity of training due to Six Sigma being disseminated to all parts of the organization. The other has a concern for management excellence and trains people from both the operational area as R&D in CI tools and techniques.
P4	It is not a widespread and widely used practice by companies, showing that there is still a lack of planning for the implementation of CI in the PDP and other R&D&I processes.
P5	It is not a widespread and widely used practice by companies. Despite being widely used to increase the commitment with the CI of those responsible for operational processes, the same strategy does not occur to the PDP or other R & D & I processes.
P6	For two of the companies studied, there are training in principles of the CI, including the managers, mainly through the Six Sigma program. But still no action to extend it effectively to the PDP. The company C, which has an area of Excellence in Innovation presents a slightly different scenario, with greater application of CI.
P7	It is not a widespread and widely used practice by companies for not be a deployment culture of CI in the PDP and not be the benchmarks possibility as occurs for CI applied to manufacturing or administrative processes.
P8	All companies use more than one CI program, but none of them has focused on the PDP's CI or other R&D&I processes. The focus of the program is still in manufacturing and in some administrative processes.
P9	Two companies (A and B) have knowledge of the principles of quality, reliability and CI in the PDP because they are trained in Six Sigma for the application of DFSS in PDP. However this knowledge is still not very widespread for CI actions/projects. In company C there is a greater concern that the PDP people apply with greater intensity the principles of quality and improvement.
P10	The use of the practice is low or null, the CI actions occur in an unstructured way, often within the PDP own activities. There is still no structure CI projects or actions with planning and separate schedules of the PDP.
P11	The companies studied are already organizing, initiating, generally, by the identification of good practices and with the intention of subsequently analyze nonconformities and generate suggestions for improvement.
P12	There is still low use of such practice by companies, in most there is an effort to mapping and modeling of processes, but only one of them already use other tools and structure CI projects to improve the PDP.
P13	Although there is a concern with the structure of the PDP, when problems occur in this process there is still no systematic research into the causes of these problems. Much is due to the belief that each development is unique and these problems are specific to that process execution.
P14	In two of the companies studied, the discussion of the problems occur in general meetings, as a way of learning to the PDP, but there is still not a way to systematically not fault the staff but to identify and solve problems.
P15	The application of metrics occurs in all companies studied, but few of this information is used as a way to foster CI actions and activities.

"Use various improvement programs that focus both on improving the product and improving the PDP" (P8), "Prepare a report of unconformities on the PDP to suggestions for improvement" (P11) and "Do not blame the PDP team when problems occur" (P14). P3 and P8 are both related to the dissemination of improvement programs in companies that impact the diffusion of improvement culture, including problem analysis (P11) and not blaming individuals (P14).

5 Conclusion

The literature review helped to identify practices that foster the implementation of CI in the PDP and other R&D&I processes, with general practices of implementation of CI and more specific practices to improve the PDP. It was possible to identify that the most cited practices in the literature are related to the dissemination of culture and principles of

CI; tools for improvement, especially VSM, and adoption of metrics for measuring the PDP for later improvements.

The most widespread program in the PDP environment in case studies companies, is Six Sigma, due to the necessary training for the use of DFSS as a model for the PDP, but the principles, methods and Six Sigma tools for improvement actions in the PDP and other R&D&I process are still little used. The diffusion agent identified as a priority was the establishment of a CI structuring area in the PDP context, with identification and prioritization of improvement projects and definition of objectives for the CI to occur.

There is a general awareness by the respondents of the CI need in the PDP and other R&D&I processes, however, it was observed that the implementation of CI in this environment is still facing difficulties mainly due to the lack of senior management commitment to the implementation of CI in the PDP. Existing practices observed in the cases result from disseminated CI culture by improvement programs deployed in operational areas and not from a specific effort to the CI in the PDP. These findings generate managerial implications, organizations can use the existing CI culture to sustain CI programs in the PDP, being attentive to the necessary changes and the need for other practices aimed at this context.

The importance of the PDP and the need for greater efficiency and better results in this process point to the relevance of the topic "Application of CI in PDP," yet, there is still no structured knowledge in the literature. There is a wide range of future work needed for greater understanding of the subject, e.g., the level of use of the practices in a larger number of companies, which are the main difficulties in implementation and whether it is possible to describe the maturity levels of use of CI in the PDP, such analyzes can promote the deployment in organizations. Many issues, such as, for example, what benefits generated by the use of CI in PDP and in R&D&I process, what tools would be most appropriate, how to structure CI actions for these processes, among others, need to be designed and studied to increase diffusion on the implementation of the CI in that context.

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Appendix A. Interview data.

Table 1A presents the views of respondents (Res.) about the presence of each of the 15 investigated practices. The values range from 0 to 3: 0 (not used), 1 (low use), 2 (medium use) and 3 (high use).

Table 1A. Use of practices in the companies.

Practice	Company A					Company B				Company C				Company D			
	Res. 1	Res. 2	Res. 3	Res. 4	Res. 5	Res. 1	Res. 2	Res. 3	Res. 4	Res. 1	Res. 2	Res. 3	Res. 4	Res. 1	Res. 2	Res. 3	Res. 4
1	0	1	2	1	1	0	1	1	0	2	2	2	1	0	0	1	0
2	1	2	2	3	2	3	3	2	2	2	3	2	2	1	0	1	1
3	2	1	3	3	3	3	3	3	2	3	3	3	1	1	3	1	1
4	0	0	2	2	0	1	0	0	0	0	0	1	0	0	2	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1	0	1	3	1	1	2	1	2	3	2	3	1	0	0	1	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	3	1	2	2	2	3	2	2	2	2	2	3	2	1	2	2	1
9	0	1	1	2	1	1	0	1	2	2	2	3	2	0	0	0	0
10	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
11	2	3	2	2	1	2	2	1	2	2	3	2	3	3	1	1	1
12	1	1	3	2	1	1	2	1	1	1	2	2	2	1	0	1	0
13	0	0	2	2	0	1	2	0	0	1	1	1	0	1	0	0	0
14	2	2	2	2	2	1	1	1	1	2	2	2	2	1	1	1	1
15	1	3	2	1	2	1	2	0	1	1	2	1	2	2	0	1	1

Table 2A presents the descriptive statistics of the views of respondents. It shows the calculation of the mean, median and mode, and the sample standard deviation. It was considered the mode, because it is the most frequent opinion. When mode had more than one value, it was considered qualitative descriptions of practical use to find the tendency that best represented the analyzed situation (gray cells in mode colluns).

Table 2A. Descriptive analysis of the opinions of those interviewed (per company).

Pratices	Mean				Median				Mode				Standard Deviation			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
1	1.0	0.5	1.8	0.3	1	0.5	2	0	1	0	2	0	0.71	0.58	0.50	0.50
2	2.0	2.5	2.3	0.8	2	2.5	2	1	2	3	2	1	0.71	0.58	0.50	0.50
3	2.4	2.8	2.5	1.5	3	3	3	1	3	3	3	1	0.89	0.50	1.00	1.00
4	0.8	0.3	0.3	0.5	0	0	0	0	0	0	0	0	1.10	0.50	0.50	1.00
5	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00
6	1.2	1.5	2.3	0.3	1	1.5	2.5	0	1	1	3	0	1.10	0.58	0.96	0.50
7	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00
8	2.0	2.3	2.3	1.5	2	2	2	1.5	2	2	2	1	0.71	0.50	0.50	0.58
9	1.0	1.0	2.3	0.0	1	1	2	0	1	1	2	0	0.71	0.82	0.50	0.00
10	0.0	0.0	0.5	0.0	0	0	0.5	0	0	0	1	0	0.00	0.00	0.58	0.00
11	2.0	1.8	2.5	1.5	2	2	2.5	1	2	2	2	1	0.71	0.50	0.58	1.00
12	1.6	1.3	1.8	0.5	1	1	2	0.5	1	1	2	1	0.89	0.50	0.50	0.58
13	0.8	0.8	0.8	0.3	0	0.5	1	0	0	0	1	0	1.10	0.96	0.50	0.50
14	2.0	1.0	2.0	1.0	2	1	2	1	2	1	2	1	0.00	0.00	0.00	0.00
15	1.8	1.0	1.5	1.0	2	1	1.5	1	1	1	1	1	0.84	0.82	0.58	0.82