Lean Product Development: an overview of the best global practices

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Abstract
The purpose of this paper is to identify the practices and indicators presented in the literature about Lean Product Development. Ninety studies were analyzed to locate trends considering Value Stream Mapping, Suppliers, Standardization, Simultaneous Engineering, Voice of the Consumer, Chief-Engineer, Modularity, Virtual Simulation, Visual Management, Learning Network and others.

Keywords: Lean Product Development, Best Practices, Literature.

Introduction

The use of Lean Product Development practices and indicators is not new to the scientific community. The history of their application illustrates two important trends. The first is that the use of practices and indicators brings significant advantages to companies, an essential characteristic for Lean product development. The second is that there is no unanimity about what practices and indicators are most appropriate.

The objective of this paper is to investigate in relevant publications from the past 20 years which practices and indicators were most used in Product Development Processes (PDP), among other important aspects that can be used to indicate trends and paths for researchers and companies.

This article will use the term “Practices” as a synonym for “best practices” and “good practices” which is summarized as techniques, methodologies, procedures or processes that were implemented and improved company performance.

According to León and Farris (2011), Lean Product Development is an approach adopted by organizations that seeks to maximize value, improve quality, decrease lead-time and product development and process costs.

This study is a theoretical review based on a search for related information found in relevant scientific publications from the past 20 years, which concern Lean Product Development. The study was conducted on the Web of Science data base using the keywords “Voice of Customer”, “Lean” and “Product Development”, “Knowledge-based system” and Benchmark”. After using the filters, 72 valid articles were considered. Table 1 shows the research steps conducted on Nov. 21, 2013.

Table 1 – Research process conducted on the Web of Science database

Keywords	**No Filter**	**Document Type**	**Language**	**Research Areas**	**Categories (7)**
		Article	***English***	***Engineering; Business Economics; Operations Research Management Science***	***Management; Engineering Industrial; Operations Research Management Science; Engineering Manufacturing; Business; Engineering Mechanical; Engineering Multidisciplinary***
"Lean" AND "Product Development"	174	82	80	66	59
"Voice of Customer"	60	29	28	22	19
"Knowledge Based Systems" AND "Product Development"	42	25	24	19	19
					97
				Abstract and Title Filters	-25
				TOTAL	**72**

The key questions to be answered in this article were:

a) How has the issue changed over the years?
b) Which authors are most cited?
c) Which PDP practices are most used?
d) Does the Lean approach appear in an explicit manner?
e) Are indicators used to monitor the PDP steps? Which ones?

Theoretical Framework and Results

This section summarizes the main Lean development practices identified in the bibliometry. Due to the restricted space and the extensive quantity of practices identified (at least 25), six were listed to facilitate the classification and the results – Voice of the Consumer (VOC), Learning Network, Modularity, Standardization and Supplier.

Clark (1987) mentioned that Lean Product Development is comprised of six techniques: supplier involvement, simultaneous engineering, cross-functional teams, integration of activities, a heavyweight team structure, and strategic project management.

- **VOC** – According to Fung, Popplewell & Xie (1998), aligning quality incentives with the Voice of the Consumer is one of the key strategies for improving an organization's competitive advantage, and assisting a company to identify clients' needs and requirements, to be able to design a product that has value. In the service sector, the importance of VOC was also observed, according to the work of Parasuraman, Zeithaml and Berry (1985, 1988) apud Yang, Chou and Ding (2011) who perceived that client satisfaction is closely related with the quality of service offered and that this quality depends on the gap between the service expected and the service perceived. Quality Function Deployment (QFD) is one of the techniques most used to capture VOC and transform it into design characteristics. QFD is a broadly accepted practice for implementing the voice of the consumer through planning of product, design and manufacturing. One of the important steps of QFD is to give priority to the voices of the client to allocate resources in a suitable manner (MADDULAPALLI, YANG & XU, 2012).
- **Learning Network** – is a practice that seeks to maintain and reuse knowledge within organizations. At companies that implement Lean product development there is a unique relationship between managers, supervisors and workers. The supervisors and managers are quite involved in all the details of the engineering project and strive to have the engineers think about and understand the problem before developing options. Knowledge is passed on through active learning and checklists (Nepal, Yadav, Solanki, 2011). Japanese authors, including Nonaka et al. (2000) affirm that knowledge should be administered using the SECI model (Socialization, externalization, combination, internalization) to transform tacit knowledge into explicit knowledge. In addition, they maintain it is important to register the lessons learned at the end of each project, considering that the problems found are also seen as opportunities for improvement. This practice includes the identification of environments that are propitious for innovation. Two terms used in this practice are "Project library" and "record lessons learned".
- **Modularity** - Modularity or the platform strategy is defined by Mahmoud-Jouini and Lenfle (2010) as "a large group of product components with standardized interfaces that are physically connected as a stable subset of a larger product and that can be shared between different final products." The authors also affirm that this strategy helps to reduce delivery time and development costs, increase quality and reliability of the product and increase flexibility of manufacturing. This is a practice directly related to the product, and applies DFx techniques such as Design for Assembly, Design for Disassembly, Design for Environment, Design for Service, Design for Six Sigma.
- **Standardization** – the standardization of a process consists in systemizing and structuring the PDP, defining the activities, sequence, duration, responsible parties, inputs, outputs and decision points, among other factors that each organization defines according to the types of projects undertaken considering time and complexity (Dal Forno et al. (2014); Rozenfeld et al. (2006). According to Morgan and Liker (2006), a standardized PDP contributes significantly to more precise communication and greater understanding in the functional areas.
- **Simultaneous Engineering** – this considers the parallels between the activities and work performed in multifunctional teams, also known as integration. In the Lean system, the term Set-Based Concurrent Engineering (SBCE) is used, which refers to an

evolution of Simultaneous Engineering and involves a multidisciplinary team from the beginning of the project to serve clients at low cost. The SBCE presents solutions to decrease the time of launching products in the market, a staff seeks to reduce the number of loops and iterations needed to finalize a design solution using the involvement of other engineering functions.

- **Supplier** – many companies have been adopting Early Supplier Involvement (ESI) for the development of goals, which strengthens long-term partnerships and decreases risks (Qudrat-Ullah, 2012). Lean development strives to increase the sharing of information for joint projects for raw materials, components and new process technologies.

Figure 1 highlights the practices listed that are being applied with greater frequency. In addition to these, others appear with the terms in Japanese and some that are not even directly related to the Lean approach are used as a complement, such as - A3 Report, the Seven Quality Tools, Poka-yoke, Design Structure Matrix (DSM), Fuzzy-front-end, Obeya, Hoshin Kanri, SWOT, FMEA, Six Sigma, Portfolio Management, Open Innovation, Stage-Gate, Kentou, Ecodesign and Green Supply Chain, Agile Projects, Kano Model and Analytic Hierarchy Process (AHP).

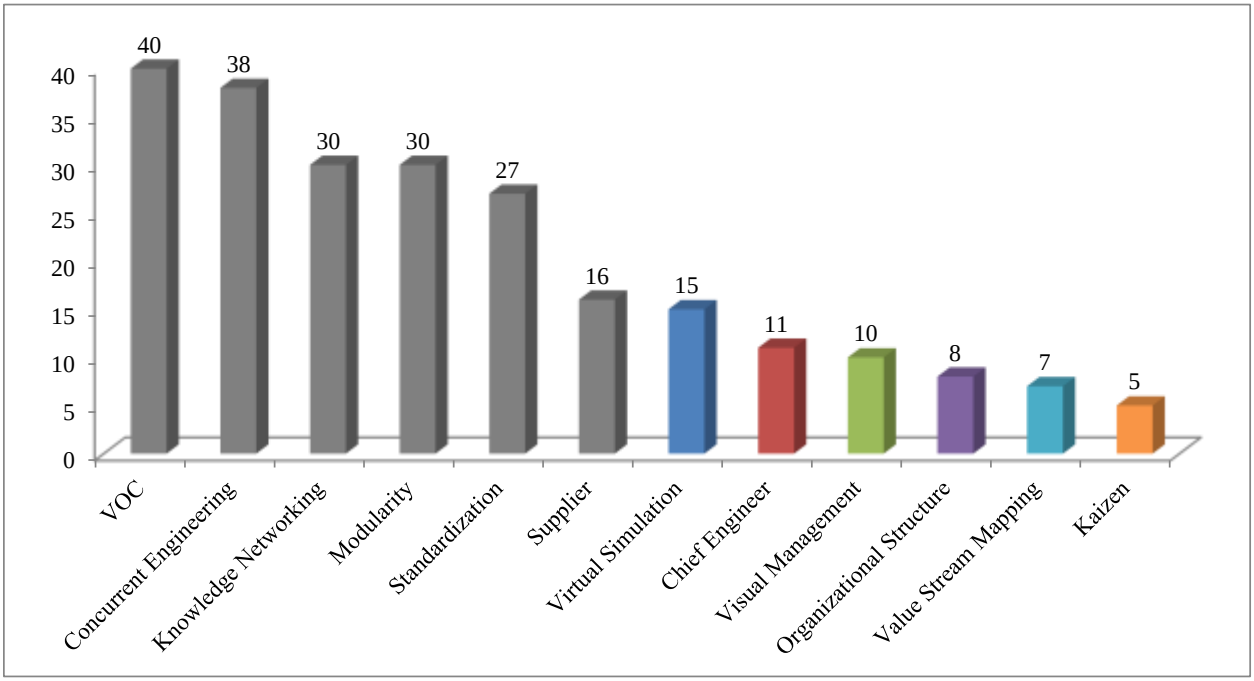

Figure 1 – Practices identified in the bibliometry

In relation to the presence of specific authors, note that there is no author or group that stands out in high impact articles and publications. Some authors that appear include:

- Shehab Abdalla (2001, 2006); Gayretli and Abdalla (1999); Wasim et al. (2013);
- Cooper and Edgett (2008); Cooper, Edgett and Kleinschmidt (2002, 2004)
- Loch and Terwiesch (1999a, 1999b)

- Morgan and Liker (2006); Liker and Morgan (2006, 2011)
- Su and Chou (2008);
- Léon and Farris (2011); Letens, Farris and Aken (2011).

Table 2 lists the four articles most cited in the bibliometry.

Table 2 – Number of citations of papers

No.	***Title***	***Citation Quantity***	***Author***	***Year***
1	*Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises*	**297**	Zhu and Sarkis	2004
2	*An intelligent hybrid system for customer requirements analysis and product attribute targets determination*	**104**	Fung, Popplewell and Xie	1998
3	*Managing the process of engineering change orders: The case of the climate control system in automobile development*	**62**	Terwiesch and Loch	1999
4	*Nobody ever gets credit for fixing problems that never happened: Creating and sustaining process improvement*	**61**	Repenning and Sterman	2001

The first publications appearing in 1995 and the peak were in 2011 with 17 publications. Lean is the term that Americans gave to Japanese practices that had been used since the early 1900s and became stronger after World War II. Thus, in the articles analyzed, an effort was made to identify if Lean appears in a direct manner, because it is known that companies often adopt the techniques and tools without them necessarily being planned within a management system. The term began to appear more explicitly after 1998 in the work of Jenner (1998); Agrawal and Graves (1999); Manohar, Shirathaya and Ferry (1999). In 60% of the publications the term Lean appeared in an explicit manner.

The use of indicators was one of the weakest points of the papers, because only 32% presented a metric to accompany the PDP. Some papers only cited other metrics in other works and it was noticed that when there is some measuring and control, it took place only at the beginning or end of the product development. This is to say that 68% of the papers did not have any performance indicator. Examples of indicators perceived were:

- Engineering Change Orders (Raudberget, 2010; Loch and Terwiesch, 1999a, 1999b);
- Number of hours of engineering (León and Farris, 2011; Oliver, Schab and Holweg, 2007);
- Percent of companies with standardized processes (Ringen and Holtskog, 2011);
- Percentage of project errors (Wasim et al., 2013; León and Farris, 2011);
- Time to estimate cost (Wasim et al., 2013);
- Number of internal meetings (Wasim et al., 2013, Zhao et al., 2011);
- Time to give price (Wasim et al., 2013);

- Break-even time (Marion and Friar, 2012);
- Percent of sales/income growth (Marion and Friar, 2012; Gottfredson and Aspinall, 2005);
- Development cost (Marion and Friar, 2012; León and Farris, 2011; Raudberget, 2010, Tuholski et al., 2009);
- Daily meetings (kentou) 20 - 30% increased efficiency of PDP (Hafer, 2011);
- Percent of productivity increase (Liker and Morgan, 2011; 29);
- Percent of quality improvement (Liker and Morgan, 2011);
- Increased employee moral (Liker and Morgan, 2011);
- Time of development cycle (lead time) (Nepal, Yadav and Solanki, 2011; Liker and Morgan, 2011, León and Farris, 2011, Raudberget, 2010, Oliver, Schab and Holweg, 2007);
- Percent of PDP activities that add value and percent of activities that are wasteful (Oppenheim, Murman and Secor, 2011, Beauregard, Bhuiyan and Thomson, 2011);
- Quality of flow outcome (León and Farris, 2011);
- Percent of products designed for reuse (Zhu and Sarkis, 2004);
- Percent of components and raw materials that are recyclable and reusable (Zhu and Sarkis, 2004);
- Return of potential problems (León and Farris, 2011);
- Improvements in tactical and operational performance (Letens, Farris and Aken (2011);
- Integration of data between internal departments (Zhao et al., 2011);
- Level of exchange of information with the main client (Zhao et al., 2011);
- Level of computer handling of the order of the main client (Zhao et al., 2011);
- Level of exchange of information about the market (Zhao et al., 2011);
- Frequency of periodic contacts with the main client (Zhao et al., 2011);
- Time of feedback for the clients (Zhao et al., 2011);
- Number of clients per point of sale (Zhao et al., 2011);
- Sharing of demand forecast with clients (Zhao et al., 2011);
- Level of exchange of information with the main supplier (Zhao et al., 2011);
- Partnership with the supplier (Zhao et al., 2011);
- Performance of the product in relation to requirements (Raudberget, 2010);
- Costs to guarantee product (Raudberget, 2010);
- Reduction of final cost of product (Raudberget, 2010);
- Increase in level of innovation (Raudberget, 2010);
- Degree of strategy adaptation (Cooper, Edgett and Kleinschmidt. 2002);
- Ability to achieve strategic growth (for example: impact on multiple units of the business) (Cooper, Edgett and Kleinschmidt. 2002);
- Potential for rewards for the company (value to the company) (Cooper, Edgett and Kleinschmidt. 2002);
- Probability of technical viability (Cooper, Edgett and Kleinschmidt. 2002);
- Probability of commercial success (competitive advantage, existence of internal competencies) (Cooper, Edgett and Kleinschmidt. 2002);
- Number of visits to the client to understand its requirements (Cooper, Edgett and Kleinschmidt, 2002);

- Number of people in the key stages (Su and Chou, 2008);
- Rate of client complaints (Su and Chou, 2008);
- Degree of technology transfer in the product (Su and Chou, 2008);
- Degree of risk of the project (Su and Chou, 2008).

Final Remarks

The theoretical study identified 12 Lean product development practices most applied in the works and of these, six (VOC, learning network, modularity, standardization, simultaneous engineering and supplier) were observed as possible attempts to systematically initiate its application at companies. It was also perceived that the introduction of practices does not occur in isolation, that is, one depends on the other and they are inter-related.

In relation to the indicators used in the PDP, more than 40 were identified in the three elements of cost, time and quality. Nevertheless, although many indicators were enumerated, it was observed that their use is incipient, because only 32% of the articles analyzed present a metrics for accompaniment and monitoring of the PDP from the perspective of Lean production systems.

Finally, the authors shared the challenges and trends for the theme, emphasizing:

- Applying Lean PDP to complex products, with high mix and low volume and at technology companies (Qudrat-Ullah, 2012, Gerhard et al, 2012; Summers and Scherpereel, 2008; Gottfredson and Aspinall, 2005);
- Seeking to better understand the value to the client to guide the engineering, demand, financial indicators and applications in services (Schulze et al., 2011; Pollack and Alexandrov, 2013; Cudney, Elrod and Uppalanchi, 2012; Yeh, 2011; Chaudha et al., 2011; Chen, 2010; Pyon, Woo and Park, 2010; Cooper, Edgett and Kleinschmidt; 2004);
- Defining a structure for the transfer and reuse of knowledge (Lindlöf, Söderberg and Persson, 2013, Schulze et al., 2011);
- Presenting a common definition and structure for Lean PDP with indicators, systemic vision and guidelines of how to apply it in a successful manner (Hoppmann et al., 2011; Letens, Farris and Aken, 2011; Beauregard, Bhuiyan and Thomson, 2011; Summers and Scherpereel, 2008; Cooper, Edgett and Kleinschmidt, 2004; Su and Chou, 2008);
- Defining systems and techniques to improve communication and integration with the supplier (Soroor et al., 2012);
- Giving greater consideration to the human abilities in the projects than the techniques (Baake, Stratil and Haussmann, 1999);
- Jointly using simulation and software during the product planning (Choudhary et al., 2011; Chin, Chan and Yang, 2008; Shehab and Abdalla, 2006);
- Using virtual simulation for the prototype (Shehab and Abdalla, 2001, 2006; Aziz and Chassapis, 2005; Bernard, 2005; Bernard and Fischer, 2002; Prasad, 2000).

As a motivation, there are papers that reinforce the benefits of applying Lean in product development that include measurements, including Walton (1999) which achieved a 30% reduction in time-to-market and Oppenheim (2004) which found a 25 to 80% decrease in scheduled time and costs (Gerhard et al., 2012).

Acknowledgements

We would like to thank the Brazilian institution CAPES (The Coordination for the Improvement of Higher Education Personnel) for its financial support for the post-doctoral fellowship grant to Dr. Fernando Augusto Pereira.

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