Chapter 3
Lean Product Development (LPD) Enablers for Product Development Process Improvement

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Abstract The enablers are recommended to improve the performance of Lean New Product Development (NPD) processes. This chapter presents an alternative to select enablers for improving the implementation of Lean NPD according to the difficulties of the company's NPD process. Based on this literature review, a questionnaire was developed to identify the level of implementation for the Lean NPD enablers and the frequency of occurrence of each problem in the portfolio of NPD projects. The likelihood of the implementation of the Lean NPD enabler to decrease the frequency of NPD problems is represented by the correlation level between Lean NPD enablers and problems. The comprehension around this subject allows project managers to drive the NPD process improvement to lean culture, saving resources and maximizing the benefits of this effort.

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3.1 Introduction

Lean product development (LPD) is the application of lean thinking, originally conceived for manufacturing processes, in New Product Development (NPD) processes. LPD departs from the customer's perception of value to create new and profitable values streams within the organization, exploring synergies between processes, people, tools, and technology (Kennedy 2003; Slack 1999). Browning and Worth (2000) emphasize that the concept of LPD goes beyond the goal of waste elimination: it aims at maximizing the value added to customer, shareholders, employees, society, and suppliers. The concept of LPD has been given increasing practical significance by companies that have succeeded in improving their manufacturing processes, and find that product design is the new operations bottleneck (Reinertsen 2009). Besides the widely known lean principles, this implementation comprises the application of numerous interrelated enablers, such as the existence of chief engineer, employee empowerment, customer focus, early problem solving, minimal constraint and value stream mapping.

There are several ways to identify these enablers for NPD in the literature, such as practices (Khan et al. 2013), principles (Cooper and Edgett 2008) and critical success factors (Nepal et al. 2011). These enablers are recommended to improve the performance of Lean NPD processes. It might be complex for a practitioner to define a comprehensive approach to improve the NPD process for a specific organization. Moreover, the companies still have limited resources for implementing several Lean NPD enablers simultaneously in their NPD process. Therefore, this paper presents an alternative to select enablers for improving the implementation of Lean NPD according to the difficulties of the company's NPD process.

This paper investigates which LPD enablers impact or influence the improvement of usual problems in companies' NPD process. Based on the comprehension of such influence, it is possible to identify and select a set of LPD enablers that will allow the mitigation of NPD problems occurrence. The aforementioned association was determined and validated through a survey carried out with 64 Brazilian companies. First, we assessed the frequency of occurrence of product development problems in our sample of companies using an adapted version of the questionnaire proposed by Paula et al. (2012). Next, we assessed the implementation level of LPD enablers most frequent cited in literature. Correlations between LPD enablers and NPD problems from the two questionnaires were calculated and analyzed.

3.2 LPD Enablers

Several methods have been proposed to improve the traditional product development process (Clark and Wheelwright 2010; Eppinger 2002). Such methods, although providing some benefits to companies, do not seem sufficient to achieve

the breakthrough improvements that characterize LPD (Letens et al. 2011; Liker and Morgan 2011; Morgan and Liker 2008). Khan (2012) states that research is still required in order to distinguish between the most critical enablers and those which can be substituted with other equivalents. Field research may also be required to determine whether or not these enablers have presence in industry.

Ballé and Ballé (2005) comment that any of the enablers, worthwhile as they may be, taken out of the system will not yield significant efficiency gains in the development process. Moreover, no integrated framework of the identified LPD enablers has been put forward in the surveyed literature, nor has a methodological guide been formulated to support the application of lean thinking on an engineering project (Dekkers et al. 2013; Reis et al. 2013; León and Farris 2011; Jayanth et al. 2010). Table 3.1 consolidates the frequency of appearance of LPD enablers in literature.

3.3 NPD Problems

The problems addressed by NPD literature form two groups. The first of these are concerned with development process effectiveness; the subsequent market success of the newly developed product (Hines et al. 2006). Specific problems within this group include lack of alignment of the product development strategy with the wider business strategic plan, unnecessary development activity, lack of understanding of customer requirements, and ultimately high new products failure rates (Graebsch 2005; Haque and Moore 2004; Bauch 2004).

The second group of problems is concerned with the efficiency of the development process itself. These include the lack of a formal or standardized process, ineffective control of high volume development environments, poor internal communications and lack of common focus (Reinertsen 2009; Oppenheim 2004). They also include an inability to improve or learn from mistakes, and ultimately poor project deadline achievement and fiscal control. As a consequence of this problem-solution focus, the LPD literature adopts as its major theme of study the identification of the best practices associated with alleviating these problems (Hoppmann et al. 2011; Kato 2005). Table 3.2 shows the appearance frequency of the main problems cited in NPD literature.

3.4 Method

The research method was divided into two stages: (i) questionnaire development and data collection; and (ii) correlating LPD enablers and NPD problems. All analyses were performed using SPSS® v.18 software.

Some criteria were used to select the companies and the respondents. First, the studied companies needed to be undergoing a lean implementation at both the shop

Table 3.1 LPD enablers and references

LPD Enablers	Ward et al. (1995)	Sobek et al. (1998)	Sobek et al. (1999)	Kennedy (2003)	Oliver et al. (2004)	Kato (2005)	Hines et al. (2006)	Ward (2007)	Matsui et al. (2007)	Morgan and Liker (2008)
Chief Engineer (technical leadership)	*	*	*	*	*			*	*	*
Integrating/target events	*		*	*	*		*	*	*	*
Set-based concurrent engineering	*		*	*	*			*	*	*
Employee empowerment/ individual responsibility		*		*			*	*	*	*
Checklists	*	*	*	*				*	*	*
Standardization (skills, process, design)		*		*	*			*	*	*
Product development value focus				*			*	*	*	*
Technical design standard/ rules			*	*			*		*	*
Knowledge focus				*	*			*	*	
Multi project management (portfolio)		*					*	*	*	*
Extensive prototyping	*	*	*	*				*		*
Learning cycles			*	*	*			*	*	*
Expert workforce development		*		*			*	*	*	*
Customer focus							*	*	*	*
Vision shared company (honshin management)				*		*	*	*	*	*

(continued)

Table 3.1 (continued)

LPD Enablers	Ward et al. (1995)	Sobek et al. (1998)	Sobek et al. (1999)	Kennedy (2003)	Oliver et al. (2004)	Kato (2005)	Hines et al. (2006)	Ward (2007)	Matsui et al. (2007)	Morgan and Liker (2008)
Knowledge databases (searchable know-how database)				*		*	*			*
Knowledge/information pull (right place at right time)				*				*	*	*
Supplier concurrent engineering	*					*		*	*	*
Trade off curves	*	*					*			*
Knowledge flow/cadence				*				*	*	*
Design structure functional plan	*		*			*	*			*
Obeya (collaboration) team room				*				*	*	*
Value Stream Mapping (VSM)								*	*	*
Keiretsu (interlocking suppliers)	*			*		*			*	*
Systems thinking						*		*	*	*
Visual management/control				*					*	*
Knowledge reuse				*				*	*	*
A3/problem and action report		*						*		*
Design concept matrix			*				*		*	*

(continued)

Table 3.1 (continued)

LPD Enablers	Ward et al. (1995)	Sobek et al. (1998)	Sobek et al. (1999)	Kennedy (2003)	Oliver et al. (2004)	Kato (2005)	Hines et al. (2006)	Ward (2007)	Matsui et al. (2007)	Morgan and Liker (2008)
Cross functional teams	*						*		*	*
Quality function deployment (QFD)	*	*					*			*
Digital engineering (simulation and analysis tools)	*									*
Levelled workload							*			*
Standard architectures/ common parts		*			*					*
Nemawashi (consensus decision making)			*						*	*
Kaizen (continuous improvement)				*			*		*	*
Hansei (lesson learned/ reflection)									*	*
Product lifecycle plan (strategy)		*					*			
Process sheets (manufacturing process per part)										*
Concept Paper/blueprint	*	*					*			*
Root cause analysis									*	*
Competitor benchmark Report										*
Design automation (*Jidoka*)										*

(continued)

Table 3.1 (continued)

LPD Enablers	Kennedy et al. (2008)	Cooper and Edgett (2008)	Gautam and Singh (2008)	Oehmen and Rebentich (2010)	Oppenheim (2011)	Letens et al. (2011)	David and Goransson (2012)	Khan (2012)	Wang et al. (2012)	Dal Forno et al. (2013)
Chief Engineer (technical leadership)	*	*	*	*	*	*	*	*	*	*
Integrating/target events	*	*	*	*	*	*	*	*		*
Set-based concurrent engineering	*	*	*	*	*	*	*	*		*
Employee empowerment/ individual responsibility	*	*	*	*	*			*	*	*
Checklists	*	*			*		*	*	*	
Standardization (skills, process, design)			*	*	*		*	*	*	*
Product development value focus	*		*	*	*	*		*	*	*
Technical design standard/ rules	*		*	*	*		*	*	*	*
Knowledge focus	*		*	*	*		*	*	*	*
Multi project management (portfolio)		*	*		*	*	*	*		*
Extensive prototyping		*	*		*		*	*	*	
Learning cycles	*				*	*		*	*	*
Expert workforce development	*		*	*	*			*		*

(continued)

Table 3.1 (continued)

LPD Enablers	Kennedy et al. (2008)	Cooper and Edgett (2008)	Gautam and Singh (2008)	Oehmen and Rebentich (2010)	Oppenheim (2011)	Letens et al. (2011)	David and Goransson (2012)	Khan (2012)	Wang et al. (2012)	Dal Forno et al. (2013)
Customer focus	*		*	*	*		*	*		*
Vision shared company (honshin management)		*			*			*	*	*
Knowledge databases (searchable know-how database)		*	*		*	*		*	*	*
Knowledge/information pull (right place at right time)	*		*	*	*		*	*		*
Supplier concurrent engineering				*	*	*		*	*	*
Trade off curves			*	*	*		*	*		*
Knowledge flow/cadence	*	*			*		*	*		*
Design structure functional plan				*	*		*	*		*
Obeya (collaboration) team room	*		*	*				*	*	*
Value Stream Mapping (VSM)	*			*	*		*	*	*	*
Keiretsu (interlocking suppliers)				*			*	*		*

(continued)

Table 3.1 (continued)

LPD Enablers	Kennedy et al. (2008)	Cooper and Edgett (2008)	Gautam and Singh (2008)	Oehmen and Rebentich (2010)	Oppenheim (2011)	Letens et al. (2011)	David and Goransson (2012)	Khan (2012)	Wang et al. (2012)	Dal Forno et al. (2013)
Systems thinking				*	*	*		*		*
Visual management/ control				*	*	*		*	*	*
Knowledge reuse		*			*	*		*		*
A3/problem and action report	*	*	*		*		*	*		
Design concept matrix			*	*	*			*		
Cross functional teams			*	*			*	*		
Quality function deployment (QFD)		*	*		*			*		
Digital engineering (simulation and analysis tools)	*	*	*		*			*		
Levelled workload				*	*			*	*	*
Standard architectures/ common parts			*	*		*		*		
Nemawashi (consensus decision making)		*	*		*			*		
Kaizen (continuous improvement)					*			*	*	
Hansei (lesson learned/ reflection)	*			*	*			*	*	

(continued)

Table 3.1 (continued)

LPD Enablers	Kennedy et al. (2008)	Cooper and Edgett (2008)	Gautam and Singh (2008)	Oehmen and Rebentich (2010)	Oppenheim (2011)	Letens et al. (2011)	David and Goransson (2012)	Khan (2012)	Wang et al. (2012)	Dal Forno et al. (2013)
Product lifecycle plan (strategy)					*	*	*	*		
Process sheets (manufacturing process per part)		*			*			*	*	*
Concept Paper/blueprint		*						*		
Root cause analysis	*							*		
Competitor benchmark Report		*						*		
Design automation (*Jidoka*)								*		

Table 3.2 NPD problems and references

NPD Problems	Dal Forno et al. (2013)	Meybodi (2013)	Reis et al. (2013)	Wang et al. (2012)	León and Farris (2011)	Letens et al. (2011)	Liker and Morgan (2011)	Oppenheim (2011)	Oehmen and Rebentich (2010)	Reinertsen (2009)	Cooper and Edgett (2008)	Pessoa (2008)
Project leader without formal authority				*	*		*	*	*	*		
Achieve true cross-functional integration		*		*		*	*		*	*	*	
Lack of feedback		*		*	*	*		*	*	*	*	
No partnership with suppliers		*	*	*	*		*	*			*	*
Lack of product portfolio strategy					*		*		*		*	*
LPD measurement system					*				*		*	
No IT integration	*	*	*				*	*	*			
Poor operational decision making process					*	*			*	*		*
Lack of discipline	*		*		*		*					
Lack of knowledge reutilization	*		*		*	*						
No simultaneous engineering		*	*		*	*						

(continued)

Table 3.2 (continued)

NPD Problems	Dal Forno et al. (2013)	Meybodi (2013)	Reis et al. (2013)	Wang et al. (2012)	León and Farris (2011)	Letens et al. (2011)	Liker and Morgan (2011)	Oppenheim (2011)	Oehmen and Rebentich (2010)	Reinertsen (2009)	Cooper and Edgett (2008)	Pessoa (2008)
Coordination and time-consuming activities						*		*	*	*		*
Lack of project vision sharing						*		*				*
Inexistence of leveled workload		*					*	*	*			

NPD Problems	Schuh et al. (2008)	Ward (2007)	Baines et al. (2006)	Hines et al. (2006)	Bauch (2004)	Haque and Moore (2004)	Oliver et al. (2004)	Tsinopoulos and McCarthy (2002)	MIT (2001)	Browning and Worth (2000)	Cusumano and Nobeoka (1998)	Karlsson and Ahlstrom (1996)	Womack et al. (1991)
Project leader without formal authority	*		*				*	*	*	*	*	*	
Achieve true cross-functional integration			*		*		*		*	*	*	*	
Lack of feedback	*	*		*			*				*		
No partnership with suppliers							*					*	
Lack of product portfolio strategy	*			*		*			*		*		

(continued)

Table 3.2 (continued)

NPD Problems	Schuh et al. (2008)	Ward (2007)	Baines et al. (2006)	Hines et al. (2006)	Bauch (2004)	Haque and Moore (2004)	Oliver et al. (2004)	Tsinopoulos and McCarthy (2002)	MIT (2001)	Browning and Worth (2000)	Cusumano and Nobeoka (1998)	Karlsson and Ahlstrom (1996)	Womack et al. (1991)
LPD measurement system	*					*	*		*	*	*		*
No IT integration		*	*		*			*					
Poor operational decision making process	*			*				*		*			*
Lack of discipline		*			*			*	*	*			*
Lack of knowledge reutilization		*	*						*		*		*
No simultaneous engineering			*				*				*	*	
Coordination and time-consuming activities					*					*		*	
Lack of project vision sharing				*	*							*	
Inexistence of leveled workload				*		*							

floor and administrative areas. Second, the geographic location was restricted for companies placed in the South of Brazil, in order to reduce any effect of external environment (e.g. availability of skilled labor). The non-random selection of companies for surveys is a common approach in other studies (e.g. Saurin et al. 2010; Boyle et al. 2011).

Furthermore, a minimum 5-year experience in lean implementation and product or process development was required for all survey respondents. Such sample characteristics were similar to previous studies about lean, namely: (i) to limit the sample to a specific geographical location (Sanchez et al. 2011; Bhasin 2012) and; (ii) to emphasize experienced companies in lean implementation (Shah and Ward 2007). The questionnaires were sent and received by email during the first quarter of 2014.

Table 3.1 was used to develop questionnaire about LPD enablers. Enablers that appeared to be overlapping were merged, while others that combined multiple practices were divided (Table 3.3). A scale from 0 to 9 was used to assess the intensity of the adoption of the LPD enablers, in which 9 denotes full adoption and 0 the lack of adoption of each enabler.

A list of frequent product development problems proposed by Paula et al. (2012) was used to develop the questions about the NPD problems. The initial 52 typical product development problems were classified into categories of NPD problems that appeared in the NPD literature (Table 3.2). Six of those problems were merged with others as they overlap similar meanings. Table 3.4 presents the 44 NPD problems and 13 categories. The questionnaire asked the frequency at which each problem occurred at the company using a 6-point scale, from 1 (very rare) to 6 (very frequent). The procedure used to validate the questionnaire was the Cronbach's alpha. Cronbach alpha was assessed to assure the internal consistency of the questionnaire. Values above 0.7 were considered enough to validate questionnaire's internal consistency (Hair et al. 2006). The following step was to investigate the relationship between the LPD enablers and NPD problems. A Pearson's correlation analysis was used, as it measures the relationship between two quantitative variables (Rencher 2002).

3.5 Results

The internal consistency of the entire group of variables was very high, with a Cronbach's alpha of 0.977 and 0.968, for the LPD enablers and problems, respectively. The correlation analysis between the 30 LPD enablers and the 44 NPD problems resulted in a matrix with i-enablers (i = 1, …, 30) and j-problems (j = 1, …, 44). Table 3.5 shows all correlations that are significant at 0.05 and 0.01 levels. From the 1320 possible correlations, 694 were considered significant and presented a negative correlation. The fact that there were no significant positive correlations is logical, as LPD enablers are expected to reduce the presence of problems. However, a few problems presented significant correlation with more

Table 3.3 LPD enablers

Enablers
LE-1-Multiple alternatives (designed)
LE-2-Delaying specification
LE-3-Minimal constraint
LE-4-Extensive simulation/prototyping (possibly including full-scale models)
LE-5-Early problem solving
LE-6-Test-then-design
LE-7-Convergence on optimum solution
LE-8-Supplier strategy (supplier types and interlocking)
LE-9-Supplier set-based concurrent engineering
LE-10-Mistake proofing
LE-11-Design in quality
LE-12-Robust design methods
LE-13-Integration/target events
LE-14-Value stream mapping
LE-15-Customer-focus (customer needs/wants)
LE-16-Multi-project plan and strategy
LE-17-Cross-functional module development teams and manufacturing involvement
LE-18-Knowledge/information flow/cadence/pull (in right place at right time)
LE-19-Knowledge reuse
LE-20-Expert workforce development
LE-21-Mentoring by senior employees
LE-22-Test-to-failure
LE-23-Rapid learning/comprehension
LE-24-A3 group problem solving
LE-25-Learning cycles (Plan-Do-Check-Act)
LE-26-Root-cause analysis and 5 whys
LE-27-Employee empowerment/individual responsibility
LE-28-Lessons learnt reflection process
LE-29-Standardization of processes, skills and design methods
LE-30-Separating research from development

than one enabler, which indicates that the problem occurrence would be significantly reduced if simultaneously applied such enablers. This finding provides companies an orientation with regards to the application of a proper set of enablers in order to mitigate NPD problem's frequency. Moreover, the strongest correlations are also highlighted in Table 3.5.

Out of the thirty studied LPD enablers, two of them did not present a significant correlation with any of the listed NPD problems: LPD enablers 1 (Multiple alternatives) and 4 (Extensive simulation/prototyping). Although the literature suggests

Table 3.4 LPD problems and categories

Problems		Categories
P1	Lack of teams management	Project leader without formal authority
P2	Project coordinator not prepared to perform expected duties	
P3	Lack of team empowerment	
P4	Many hierarchical levels which delay functional teams integration	Achieve true cross-functional integration
P5	Not effective cross-functional teams	
P6	Teamwork not stimulated	
P7	Low improvement ideas generation	Lack of feedback
P8	Communication and information sharing among areas is not organized and systematic	
P9	There is no clear guidelines or priorities definition	
P10	The project is incompatible with the production capacity	No simultaneous engineering and partnership with suppliers
P11	No systematic approach for interacting with customers/suppliers	
P12	Inexistence of a problem solving evaluation process for product development	
P13	Product development process does not start from the proper sector	
P14	No strategic definition at the beginning of product development	Lack of product portfolio strategy
P15	No business focus	
P16	Lack of market orientation (no trends identification)	
P17	Inexistence of product strategic planning	
P18	Lack of a systematic product performance evaluation through metrics	LPD performance measurement system
P19	Project exclusively controlled based on timeline	
P20	Lack of performance analysis regarding milestones and final results achievement	
P21	No systematic follow up for product development process performance	
P22	Insufficient search for information	No IT integration
P23	Delays or improper information flow during projects development	
P24	No information system integration	
P25	Low utilization of product development supporting tools	
P26	Without a consistent decision making process which delaying projects	Poor operational decision making process
P27	No involvement and commitment from senior management resulting in delays on decision making	
P28	No scope change management that assess the impact of decisions	

(continued)

Table 3.4 (continued)

Problems		Categories
P29	Lack of rigour in the pursuit of failures root-causes	Lack of discipline
P30	Low compliance to activities' deadlines	
P31	Lack of a responsibility definition for involved individuals	
P32	No formal knowledge control and management among projects	Lack of knowledge reutilization
P33	Lack of a systematic knowledge storage along product development	
P34	Process highly dependent on individual capacity and knowledge	
P35	Lack of knowledge regarding product development supporting tools	
P36	Loss of time due to lack of synchronization in workflow	Coordination and time-consuming activities
P37	Capital approval process is not performed in time	
P38	No formal methodology for product development	
P39	Product development teams do not know company's strategic vision	Lack of project vision sharing
P40	Lack of perception that the product development is a business process	
P41	Lack of products information sharing among company's employees	
P42	Lack of proper equipment	Inexistence of levelled workload
P43	There is excessive centralization of development work in a sector or area	
P44	No activity definition and detailement	

that the enabler "Multiple alternatives" is an important enabler in the LPD implementation, results show that it does not present a significant correlation with most cited NPD problems. Many authors from LPD literature (David and Goransson 2012; Khan 2012) proposed a strong relationship between NPD problems and the process of set-based concurrent engineering, which, among its main enablers, include the practice of exploring multiple alternatives. However, Kato (2005) and Gautam and Singh (2008) argue that stressing a wide variety of alternatives in a NPD process may lead to dubious consequences; i.e., if, on the one hand the discussion of multiple alternatives can bring innovative solutions, on the other, it may result in loss of focus on the customer and what he perceives as value. Thus, based on this study sample, this enabler is not significantly influential for problems frequency reduction.

Table 3.5 Correlation between LPD enablers and NPD problems

LPD enabler	NPD problems								
	Project leader without formal authority			Achieve true cross-functional integration			Lack of communication and feedback		
	P1	P2	P3	P4	P5	P6	P7	P8	P9
1									
2									
3									
4									
5	−0.354*				−0.446**				
6									
7		−0.309*			−0.418**				
8		−0.379*			−0.342*	−0.315*			
9	−0.311*	−0.398**			−0.367*	−0.368*		−0.322*	−0.435**
10	**−0.490****	−0.363*	−0.337*		**−0.456****	**−0.495****			−0.338*
11	**−0.469****	**−0.585****			−0.374*	−0.314*			
12	**−0.503****	**−0.540****	−0.324*		**−0.539****	−0.414**			−0.369*
13	−0.434**	**−0.559****	−0.328*		**−0.532****	−0.366*			−0.364*
14	−0.408**	**−0.457****			**−0.455****	−0.309*	−0.354*		
15	−0.393**	**−0.453****	−0.332*		−0.359*				
16		**−0.521****			−0.316*			−0.428**	
17	**−0.503****	**−0.650****			**−0.570****	**−0.485****		−0.372*	−0.372*
18	**−0.565****	**−0.617****	−0.335*	−0.340*	**−0.519****	−0.430**	−0.383*	−0.326*	**−0.496****
19	**−0.520****	**−0.588****			**−0.458****	−0.357*	−0.346*		
20	−0.448**	**−0.466****			−0.436**	−0.368*			−0.366*
21	−0.343*	−0.380*			−0.440**	−0.321*			−0.319*
22	−0.431**	**−0.490****			−0.437**				−0.375*
23	**−0.526****	**−0.573****		−0.326*	**−0.527****	**−0.457****	−0.412**		**−0.545****
24	−0.391**	**−0.536****			−0.433**	−0.319*		−0.335*	−0.344*
25	−0.332*	**−0.501****			**−0.465****	−0.329*		−0.331*	
26		**−0.495****			−0.344*				
27	−0.405**	**−0.558****			**−0.566****	−0.436**	−0.335*	−0.320*	
28	**−0.518****	**−0.559****	−0.300*		**−0.583****	−0.402**	−0.317*	−0.330*	−0.489**
29	**−0.484****	**−0.533****			**−0.571****	−0.392**		−0.394**	−0.330*
30	**−0.494****	**−0.569****			**−0.578****	**−0.522****	**−0.501****	−0.375*	**−0.451****

(continued)

Table 3.5 (continued)

LPD enabler	NPD problems											
	No simultaneous engineering and partnership with suppliers				Lack of product portfolio strategy				LPD performance measurement system			
	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21
1												
2												
3										−0.358*		
4												
5	−0.331*		**−0.536****		−0.351*		−0.296*	−0.392**	−0.369*	−0.367*	−0.438**	−0.381**
6			−0.307*							−0.332*	−0.363*	
7			−0.341*						−0.307*	−0.349*		−0.329*
8			−0.399**									−0.418**
9			−0.392*					−0.352*			−0.312*	**−0.450****
10	−0.331*		**−0.532****		**−0.452****		**−0.484****	**−0.567****	−0.364*		**−0.623****	**−0.533****
11			**−0.603****					−0.278*	−0.375*	−0.342*	**−0.625****	**−0.515****
12			**−0.595****				−0.377*	−0.419**	−0.400**		**−0.551****	**−0.571****
13			**−0.478****				−0.326*	−0.362*	−0.403**		**−0.512****	**−0.577****
14			**−0.551****			−0.292*	−0.333*		−0.443**	−0.371*	**−0.451****	**−0.457****
15			−0.328*								−0.279	−0.318*
16			−0.311*								−0.330*	−0.380*
17			**−0.612****			−0.327*	−0.389**		−0.379*	−0.302*	**−0.481****	**−0.595****
18	−0.397**	−0.349*	**−0.716****			−0.395**	−0.442**	−0.409**	−0.413**	−0.308*	**−0.510****	**−0.611****
19			**−0.543****				−0.328*	−0.327*	−0.379*		**−0.498****	**−0.555****
20	−0.368*		**−0.637****				−0.392*	**−0.450****	−0.413**		**−0.509****	**−0.551****
21	−0.316*		**−0.463****								−0.354*	**−0.494****
22			**−0.606****					−0.351*	−0.349*		**−0.508****	**−0.464****
23	−0.371*		**−0.702****				**−0.464****	−0.405**	−0.443**	−0.321*	**−0.556****	**−0.623****
24			**−0.590****			−0.316*	−0.300*	−0.321*	−0.415**		**−0.510****	**−0.488****
25			**−0.567****				−0.363*			−0.314*	−0.449**	**−0.481****
26	−0.324*		**−0.528****							−0.329*	−0.399**	−0.404**
27	−0.399**		**−0.634****	−0.337*		−0.433**	**−0.505****	−0.413**	**−0.450****	−0.357*	**−0.460****	**−0.522****
28	−0.348*		**−0.703****			−0.330*	**−0.453****	−0.392**	−0.407**	−0.324*	**−0.539****	**−0.613****
29	−0.339*		**−0.612****			−0.317*	−0.412**	−0.314*		−0.343*	**−0.471****	**−0.504****
30			**−0.691****			−0.381*	**−0.562****	−0.391*	**−0.461****	−0.381*	**−0.520****	**−0.629****

(continued)

Table 3.5 (continued)

LPD enabler	NPD problems									
	No IT integration				Poor operational decision making process			Lack of discipline		
	P22	P23	P24	P25	P26	P27	P28	P29	P30	P31
1										
2										
3										
4										
5	−0.366*	−0.424**	−0.316*	−0.393**	−0.350*			−0.419**	−0.343*	−0.388*
6										
7	−0.319*			−0.389*				−0.396*		−0.339*
8				−0.392*				−0.321*		−0.407**
9				−0.443**				−0.308*		**−0.456****
10	−0.424**	−0.341*	−0.434**	−0.389*		**−0.468****		−0.435**	**−0.517****	**−0.511****
11	−0.420**			−0.382*		−0.430**		**−0.458****	−0.334*	−0.415**
12	**−0.458****	−0.435**	−0.424**	**−0.584****		−0.397**		**−0.560****	**−0.507****	**−0.594****
13	−0.446**	−0.313*	−0.337*	**−0.563****		−0.374*		**−0.581****	−0.332*	**−0.474****
14	−0.313*	−0.375*		−0.335*	−0.315*	−0.361*		**−0.547****	−0.313*	−0.407**
15				−0.378*				−0.415**		−0.409**
16	−0.401**			−0.341*				−0.373*		−0.360*
17	**−0.499****	−0.347*	−0.437**	**−0.542****		−0.444**		**−0.603****	**−0.455****	**−0.623****
18	**−0.529****	**−0.540****	**−0.493****	**−0.676****	−0.311*	−0.441**		**−0.649****	**−0.578****	**−0.631****
19	−0.362*	−0.382*		**−0.500****		−0.432**		**−0.588****	**−0.486****	**−0.513****
20	−0.424**	−0.389*		**−0.554****		−0.353*		**−0.512****	**−0.469****	**−0.566****
21				**−0.541****				**−0.511****		−0.376*
22	**−0.456****	−0.347*	−0.359*	**−0.550****		−0.359*		**−0.542****	−0.396*	**−0.462****
23	−0.446**	−0.443**	−0.444**	**−0.691****		−0.408**		**−0.708****	**−0.512****	**−0.571****
24	**−0.519****	−0.392**	**−0.452****	−0.449**	−0.316*	−0.322*		**−0.546****	−0.419**	**−0.529****
25	−0.391**		−0.338*	**−0.451****				**−0.497****	−0.361*	**−0.486****
26	−0.384**			−0.428**	−0.303*	−0.309*		**−0.463****	−0.339*	−0.404**
27	−0.420**	**−0.507****	**−0.477****	**−0.500****	−0.329*	−0.408**		**−0.582****	**−0.620****	**−0.696****
28	**−0.478****	**−0.487****	−0.452**	**−0.650****		**−0.455****		**−0.701****	**−0.563****	**−0.626****
29	−0.420**	−0.372*	−0.439**	**−0.468****	−0.333*	**−0.464****		**−0.611****	**−0.598****	**−0.598****
30	−0.**447****	**−0.516****	**−0.512****	**−0.605****		−0.405**		**−0.681****	**−0.549****	**−0.651****

(continued)

Table 3.5 (continued)

LPD enabler	NPD problems												
	Lack of knowledge reutilization				Coordination and time-consuming activities			Lack of project vision sharing			Inexistence of levelled workload		
	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44
1													
2											0.334*		
3													
4													
5	−0.389**	−0.360*		−0.380*			−0.408**	−0.432**	**−0.495****	−0.324*	−0.339*	**−0.457****	
6													
7	−0.367*		−0.321*	−0.377*			−0.404**	−0.400**	−0.438**				
8	−0.356*		−0.356*				**−0.478****	−0.396*	−0.389*			−0.349*	
9	−0.347*		−0.402**	−0.335*			**−0.470****	−0.443**	**−0.482****			−0.446**	
10	**−0.491****	−0.358*	−0.434**	−0.389*	−0.313*		−0.342*	−0.408**	**−0.491****			−0.439**	
11	−0.426**	−0.315*	−0.396**	−0.265			−0.379*	−0.406**	−0.349*	−0.412**		−0.343*	
12	**−0.467****	**−0.476****	**−0.546****	**−0.534****	−0.416**		**−0.543****	**−0.527****	**−0.568****	−0.405**	−0.323*	**−0.474****	
13	−0.426**	−0.406**	**−0.460****	−0.411**	−0.334*		**−0.549****	−0.413**	**−0.506****	−0.435**	−0.372*	**−0.450****	
14	−0.340*	−0.393**	−0.357*	−0.413**			**−0.503****	**−0.546****	**−0.541****	−0.350*		**−0.463****	
15	−0.382*		−0.401**				−0.388*						
16	−0.323*				−0.365*		**−0.461****	−0.380*				−0.355*	−0.324*
17	**−0.494****	−0.429**	**−0.482****	**−0.488****	**−0.456****		**−0.568****	**−0.531****	**−0.522****	−0.350*	−0.363*	**−0.480****	
18	**−0.505****	**−0.486****	**−0.513****	**−0.615****	**−0.510****		**−0.618****	**−0.551****	**−0.578****	−0.406**	−0.396*	**−0.530****	−0.358*
19	−0.378*	−0.403**	**−0.508****	**−0.453****	−0.422**	−0.336*	**−0.558****	−0.412**	**−0.457****	−0.375*	−0.323*	−0.392*	−0.314*
20	**−0.493****	−0.377*	**−0.475****	**−0.515****	−0.327*		**−0.610****	−0.476**	**−0.571****	**−0.496****	−0.328*	−0.388*	−0.330*
21	−0.330*	−0.297	−0.381*	−0.351*	−0.286	−0.332*	**−0.480****		−0.349*			−0.434**	
22	−0.375*	−0.390*	−0.395*	**−0.489****	−0.364*		−0.409**	−0.359*	**−0.461****	**−0.507****		**−0.466****	
23	**−0.510****	−0.407*	**−0.508****	**−0.625****	−0.402*	−0.322*	**−0.540****	**−0.480****	**−0.566****	−0.437**	−0.356*	**−0.519****	
24	−0.420**	**−0.507****	−0.398**	**−0.500****	**−0.458****		**−0.558****	**−0.514****	**−0.531****	−0.375*	−0.357*	**−0.520****	−0.357*
25	−0.360*	−0.331*		−0.441**	−0.355*		**−0.617****	−0.447**	**−0.525****			**−0.599****	−0.371*

(continued)

Table 3.5 (continued)

LPD enabler	NPD problems												
	Lack of knowledge reutilization				Coordination and time-consuming activities			Lack of project vision sharing			Inexistence of levelled workload		
	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44
26				−0.394**	**−0.472****		**−0.569****	−0.399**	−0.437**	−0.387*		**−0.613****	−0.438**
27	**−0.556****	**−0.513****	**−0.504****	**−0.591****	**−0.493****		**−0.633****	**−0.661****	**−0.682****		−0.446**	−0.439**	−0.316*
28	**−0.577****	**−0.524****	**−0.539****	**−0.582****	**−0.458****		**−0.605****	**−0.565****	**−0.612****	−0.422**	−0.369*	**−0.528****	−0.362*
29	**−0.565****	**−0.509****	**−0.530****	**−0.501****	**−0.501****		**−0.495****	**−0.527****	**−0.491****			**−0.512****	−0.342*
30	**−0.583****	**−0.461****	**−0.503****	**−0.659****	**−0.450****		**−0.608****	**−0.540****	**−0.650****	−0.403*	−0.367*	**−0.555****	

* Correlation is significant at 0.05 level
** Correlation is significant at 0.01 level

Contrary to popular belief, the results show that enabler 4 "Extensive simulation/prototyping" does not have a significant impact on any of the NPD problems. This result is somewhat surprising in light of conventional wisdom about the difficulty of developing any new product without a minimum level of simulation or prototyping within the organization. However, this result is consistent with the findings of Oliver et al. (2004) and Matsui et al. (2007), who infer that the manufacture and testing of prototypes along a product development is extremely expensive and difficult. Moreover, few companies have an exclusive area for prototyping, which makes its manufacture occur in current production lines, affecting the productive capacity and even the condition of their machinery. Moreover, since one of the main objectives of LPD implementation is NPD lead time reduction, Schuh et al. (2008) and Oliver et al. (2004) state that, especially in technology business, longer times for simulation and prototyping may cause loss in the product time to market, which impacts its innovative aspect for consumers.

Overall, the sum of correlations for each LPD enabler and all NPD problems indicate that enablers 18 (Knowledge/information flow/cadence/pull), 28 (Lessons learnt reflection process), 30 (Separating research from development), 27 (Employee empowerment/individual responsibility) and 23 (Rapid learning/comprehension) are the ones that present the strongest impact for mitigating NPD problems and, therefore, the most indicated for companies that are struggling with their NPD processes. These results are aligned with the findings of Dal Forno et al. (2013) and Oppenheim (2011), who emphasize the importance of employee involvement practices and the process of reflection and learning from past activities. However, such result neglects the company's context, whose maturity level for NPD process must be taken into account. Further, the occurrence of NPD problems must be properly considered, since they are the main input for decision on LPD enablers adoption.

3.6 Conclusion

This chapter showed an alternative to select enablers for improving the implementation of LPD according to the most cited NPD problems in literature. Among the 30 LPD enablers and the 44 NPD problems it was identified 694 significant negative correlations at 0.05 and 0.01 level. This finding provides the companies an orientation with regards to the application of the proper enablers in order to mitigate NPD problems' frequency. The correlations indicated that some LPD enablers are associated to the frequency of many NPD problems. Therefore, the comprehension around this subject allows project managers to drive the NPD process improvement to lean culture, saving resources and maximizing the benefits of this effort.

Furthermore, the results of this study are intended to complement the usual recommendation and categorization of LPD enablers based on benchmarking of previous researches. Our findings indicate that the implementation of LPD enablers matters with regards to occurrence frequency of LDP problems, although not all

enablers matter to same extent. Moreover, some results demonstrate that, although literature indicates a certain level of impact, the correlation between enablers and problems may present different impacts than the expected ones.

Each of the LPD enablers under study is associated with a significant lore about their impact on the occurrence frequency of LPD problems of companies undergoing a lean implementation. Overall, the evidence presented here suggests that the studied LPD enablers, presented in the literature as fundamental for a lean implementation, significantly affect the likelihood of LPD problems occurrence. In particular, the impact of four out of five enablers' constructs appears to be the most substantial across the frequency of occurrence of LPD problems. The influence of the enabler construct "Set-based concurrent engineering for concept generation", however, does not appear to be as significant for mitigating LPD problems occurrence as expected.

The results also indicate that there is not a fixed recipe for success since every organization starts with a different set of problems and constraints, which is supported by the findings of Singh et al. (2010) and Bhasin (2012). In general, the success of implementation of any particular management practice depends upon organizational characteristics, and not all organizations can or should implement the same set of enablers. The understanding of the company's current context, specifically its NPD problems occurrence frequency, is fundamental for the appropriate adoption of LPD enablers. According to contingency arguments, organizations should use LPD enablers that are effective to their NPD problems. Therefore, the contingency approach assumes that it is the company's context that, in the long run, determine the organizational responses in the lean implementation, whether it is on the shop floor or NPD process.

There are some limitations due to the nature of the sample used in the survey that must be highlighted. First, the respondents were mostly from companies located in the South of Brazil, their answers might be linked to regional issues, where the spread of lean may have come under local influences. Thus, as this limitation restricts the results to this geographic condition it also increases the certainty that the results apply to those companies. It is worth noting that companies of other countries may experience the same contextual conditions. Second, the sample size effectively confirmed only some relationships between the LPD enablers and NPD problems and it was not possible to reject all null hypotheses proposed. Those hypotheses that were not rejected may exist in a lower level. If that is the case, larger sample sizes can highlight those effects. Nevertheless, the exploratory nature of this research provided important evidences for developing more structured models that should be empirically tested.

Due to poor evidence in literature about the likelihood of any interdependent influence, further investigation would add more data and help to establish a holistic perspective about the problem and identify interactions among the LPD enablers and their influence over NPD problems. Such research opportunity would raise a more extensive and coherent analysis in order to really comprehend and specify the contexts in which problems are expected to occur.

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