Lean Product Development (LPD)-A Systematic Literature Review

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Abstract

Context: The major goal of development processes in software engineering is to avoid unnecessary features and to provide value driven software products. Lean product development (LPD) resolves these issues to some extent by emphasizing on reducing waste and increasing customer value. LPD is reaction based approach. The ultimate goal of lean is to eliminate waste, balance the process and to undergo demand-driven planning. Lean brings flexibility in the development and manufacturing processes. Lean works on its seven principles hence improving the development process. Objective: The main objective of this systematic literature review (SLR) is to get insight of lean product development. We aim at identifying, summarizing, and analyzing the existing high-quality primary studies on principles of Lean and discuss its positive and negative impacts. Lean's impact on various aspects of software development organizations (SDO) such as people, process and product is analyzed. The methods used by different organizations to apply lean principles to software development processes along with their models, tools and frameworks are discussed. There are several studies on LPD and there is no systematic review performed so there is need of an effective and unbiased SLR in this domain. Methodology: The selection process includes data extraction, detailed analysis and reporting of findings. Primary studies are selected by following a systematic and unbiased selection procedure according to standard PRISMA guidelines. This study highlighted five research questions which need to be addressed regarding LPD. Conclusion: Lean principles have their impact on all stages of development employing its seven principles. Chronological distribution of selected studies have shown a decreasing trend of LPD after 2014 which also justifies the need for this systematic literature review. Findings include the methods used for LPD so far and overall research productivity of this domain. This SLR also discusses more research perspectives to be considered in this domain.

CCS Concepts: • Software and its engineering • Agile software development.

Keywords: Lean Product Development, Lean Principles, Lean Management.

1 Introduction

Lean product development (LPD) has its roots in the Japanese automotive industry from many years but now it has produced a significant impact in manufacturing environments to improve organization's performance. Due to its main focus on reducing waste and increasing customer value, lean has also found its way in other domains such as healthcare, government and service industries[1]. Lean is not only confined to product development and technical aspects rather it also has its soft practices i.e. impact on human factors, business and managerial activities of an organization which are even more influential towards lean success[2]. Lean concepts have their

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origin in the Toyota production system[3]. This system regarded lean thinking as the core for developing subsystems of tools, technologies and processes [4]. LPD was introduced in Toyota Motor corporation in 1950's [5]. Due to this reason, Lean concepts have been majorly applied in automobile industry so far to produce high quality, low cost and shorter time to market products. There are seven principles of Lean which different companies apply according to their own production systems. According to [3], the seven principles are defined. Principle one is to Eliminate Waste; it means to avoid unnecessary features which do not add value to the final product. Principle two is; Integrating Quality; it states early detection of defects to improve overall quality and productivity. Principle three is Creating Knowledge; it emphasizes that knowledge should be stored in a way that makes it easies for new team members to understand the project without going into initial process of learning. Principle four is Postpone Commitments; it states that irreversible decisions should be scheduled to the last possible moment when the team will have more knowledge on the subject. Principle five is Delivering Fast; it argues that product will be delivered as soon as possible if continuous feedback is taken from customer in order to avoid requirements change. This can be done by dividing project in iterations. Principle six is Respect People; it focuses on enabling the team rather than controlling them by trusting their way to work so that processes can be improved and final decisions should take into account everyone's suggestions. Principle seven is to Optimize the Whole; this principle focuses on improvement of local processes to get global advantage.

The new focus of lean is on economic, environmental and social sustainability[5]. Economic sustainability includes increased economic value due to reduction of waste. Environmental sustainability is about resource usage and social sustainability focuses on employees' needs like training and education, giving them equal opportunity, autonomy and motivation to work.

Lean manufacturing (LM) has also some negative effects along with positive ones. The negative effects and their causes are stated in [6]. It is stated that 40% of all of the projects showed negative effects. Many of these negative effects emerged due to poor management and control of project.

There is significant research carried out in LPD but the chronological distribution shows that quality research contribution in LPD has been decreased since 2014 (see Figure 1). Moreover, there is no Systematic Literature Review (SLR) to present the emerging trends in this domain. This SLR attempts to fill this gap and it will also identify more research perspectives to be considered in this domain. The timespan considered for this research is 2013-2018.

Our contribution is to identify the overall research productivity in this domain. Due to limitation of number of pages, only the research productivity is provided and some methods of Lean Product Development (LPD) are enlisted. A brief discussion is also provided highlighting some concepts related to Lean. Through a quality assessment process, this study ensures that only high-quality studies meeting certain quality scores are considered for the inclusion.

This study is organized as follows: Section 2 elaborates the detailed research methodology including all research questions, data sources and Inclusion, Exclusion & Quality

criteria. Subsequently, section 3 reports results and discussion of selective research questions. Discussion is concluded in section 4.

2 Research Methodology

A Systematic Literature Review (SLR) aims at identifying, evaluating and interpreting available research related to a specific field of interest[7]. An SLR needs to follow an unbiased search plan.

We aim to fill the gap of SLR in LPD domain using SLR guidelines by Kitchenham [7]. This review process comprises of three main phases; Planning, Conducting and Reporting. These phases need to be conducted in a systematic and disciplined way (see Table 1).

Table 1: Systematic Literature Review Process

Phases	Steps
Planning	Research Objective
	Selection of Online-Digital Libraries
	Formulation of the Query String
	Definition of Inclusion and Exclusion criteria
Conducting	Study Selection
	Data Synthesis
Reporting	Proposed Plan/ Result
	Report formatting

A Research Questions

The primary research question of this SLR is: "What is overall research productivity of lean product development?" Formulated research questions are listed (see Table 2).

Table 2: Research Questions

RQ#	Research Questions
RQ1	Which methods have been used so far to apply lean principles to product development?
RQ2	What is effect of lean principles on agile development?
RQ3	Is there any reported problems while applying lean principles to product development?
RQ4	How LPD principles are improving current development paradigms?
RQ5	What is overall research productivity in this domain?

B Search Criteria

The timespan of 2013-2018 is considered to conduct this SLR. A step by step filtration process is used to extract the related studies from the databases. Firstly, the studies are acquired from the databases using manual and automated search. Secondly, studies are filtered on the basis of

title and abstract considering certain defined and related keywords. Finally, full-text reading of selected research papers have been performed to further clarify the relevance of studies.

C Data Sources

Data has been gathered using both automated and manual search. Automated queries are applied on popular search engines; IEEE Xplore, ACM Digital Library, Springer and Science Direct. In springer, results have been gathered for both computer science and business & management disciplines. For manual search, Google Scholar is considered.

D Formulation of Search String

After collecting Meta search terms, following are the search strings used for respective data bases considering timespan (2013-2018).

Springer: with at least one of the words ***product* design* software "life cycle" principle develop* manage*** where the title contains ***lean***.

Science Direct: tak(lean)AND tak (product* OR design* OR software OR "life cycle" OR principle OR develop* OR manage*)

IEEE: "Document Title":lean AND ("Document Title": product* OR "Document Title":design* OR "Document Title":software OR "Document Title":"life cycle" OR "Document Title":principle OR "Document Title":develop* OR "Document Title":manage*)

ACM: where **TITLE** matches all ***lean*** and where **TITLE** matches any ***product* OR design* OR software OR "life cycle" OR principle OR develop* OR manage****

E Inclusion, Exclusion and Quality Assessment criteria

Inclusion and exclusion criteria is used to select potentially relevant studies from data sources to answer the research questions in this SLR. This criteria is applied to each selected study retrieved in the initial phase of the study selection procedure. The inclusion, exclusion (IE) and quality assessment (QA) criteria employed in this SLR is listed (see Table 3 and Table 4).

Table 3: Inclusion and Exclusion Criteria

Inclusion Criteria	
IC1	Peer reviewed articles
IC2	Articles showing effect of lean principles on development paradigms
IC3	Articles discussing lean principles
IC4	Inclusion of latest study in case of multiple studies on the same theme
IC5	Articles published during timespan (2013-2018)
IC6	Articles answering one or more research questions
Exclusion Criteria	
E1	Studies other than English language
E2	Studies having sole focus on agile development
E3	Short papers, surveys, review papers and Posters

Table 4: Quality Assessment Criteria

QC#	Quality Considerations
QC1	Is the study discussing LPD principles?
QC2	Is the study discussing method used by LPD?
QC3	Is the study having clearly specified goals and objectives related to LPD?
QC4	Is there any comparison of LPD with other development paradigms?
QC5	Is the study highlights any limitation of LPD?

F Selection of Studies

Data extraction forms are designed. Studies are selected based on their fulfillment of quality criteria and research questions answered in each respective study. The study selection procedure adopted for this SLR consists of four steps and is according to the standard PRISMA guidelines for systematic review (see Figure 1). The steps include

1) Identification

Studies are selected using manual and automated search. Queries are used for automated search on different search engines.

2) Screening

Selected studies are filtered first on the basis of relevant title and then abstract basis screening is performed to further select only relevant studies.

3) Eligibility

Screened studies are accessed for full-text to check their credibility.

4) Included

Final filtered studies are included.

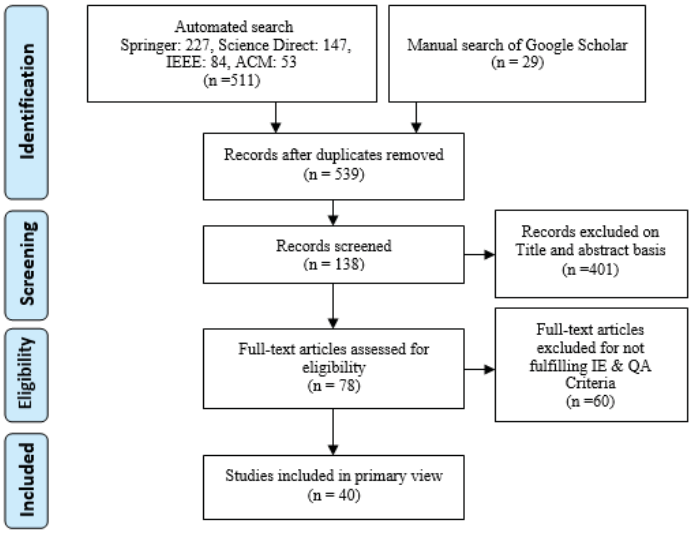

Figure 1: Study Selection Process of the SLR

3 Results and Discussion

Software development and manufacturing are two fundamentally different domains. The implementation of lean software development is explained in [8] by conducting case study in Ericsson R&D Finland and analyzing its factors of success. Also, the three challenges of lean software development are identified as achieving flow i.e. all departments of an organization should work in one direction of lean thinking, transparency and creating a learning culture which requires time and commitment of team members. This case study emphasizes that value and quality are more important concepts as compared to reduction of waste; which consequently leads to more customers and high quality.

A Lean Enabled Accelerated Planning (LEAP)

Lean Enabled Accelerated Planning (LEAP) is being discussed in [9] by conducting a case study on an international company, Rockwell Collins. This explains that planning can be done more efficiently by involving key stakeholders in up-front planning to identify risks and schedule activities to improve customer satisfaction and performance.

B Lean ERP

There is an idea of combining lean thinking with information technology in [10] to develop an Enterprise Resource Planning (ERP) based lean implementation. This study relates lean principles with ERP framework to get the desired best working system. It suggests that continuous lean learning by team is very necessary to make this new implementation successful. However, in contradiction to this, it is mentioned in [11] that lean management and ERP systems contradict in many aspects. Lean focuses on low cost, simplicity and transparent information whereas it is stated that ERP tends to be complex, costly and is not transparent. Moreover, lean is flexible to accommodate changes while ERP is inflexible because of high costs of change. So most organizations combine these two concepts which is called Lean ERP. A case study was conducted in marine sector as mentioned in [12]. It describes that the implementation of only lean tools will not suffice for achieving leanness in development process. Rather an organization must learn continuously about lean thinking to get better results.

C Impact of Lean on phases of product development

According to [13], lean principles have great impact on product development processes and tend to change the process in a drastic way. It shows that principles of lean; “Respect people” and “Optimize the Whole” have major influence on stages of development. Moreover, principle of “Integrating Quality” has an impact on product design stage.

D Waste reduction

According to [14], one kind of waste reduction is to minimize the idle time of an artifact in development process after its complete implementation. It will increase efficiency because early feedback will be available. There is a ready buffer containing most important features from which developer chooses at the moment. This scheme uses value stream mapping (VSM). The categories of wastes are mentioned in [15] which are waiting, over-production, rework, motion, over processing, inventory and transport.

E Lean Manufacturing (LM)

According to [16], there are seven dimensions of lean manufacturing (LM) stated as workforce, manufacturing process & equipment, supplier, manufacturing planning & scheduling, customer, visual information system and product development & technology. As it is mentioned in [6] that there is not even one project which is without negative effects. The negative effects imposed by LM are: 1. Late or cancelled deliveries known as Fall-outs due to internal problems, 2.Quality issues 3.Increased stock 4.Customer dissatisfaction leading to damaged reputation of company 5.Reduced sales 6. Fluctuation of core employees 7. Increased cost. The main causes of these mentioned effects are identified in the same paper which are; 80% of focus on direct effects i.e. man power and cost, 73% goes to inconsistency in planning, 70% are due to focus on whole project instead of individual iterations, 63% are related to scope i.e. not understanding it well and 63% are due to inability of determining risk at initial levels.

F Sustainability in Lean

According to analysis in [17], lean is 20% process and 80% mindset which means that in order to transform your processes to lean, every member from higher to lower hierarchy in team should be involved in process of continuous improvement. Sometimes the lean philosophy does not seem to be sustainable or undergoes failure. For this issue to handle, an assessment tool was introduced in [18] to allow companies to access lean and implement it in an effective way. There are also two more solutions proposed in [19] which are organizational memory building and institutionalizing. Organizational memory can be in the form of declarative memory including facts & events, procedural memory including procedures & functions and emotional memory of past events. This can be preserved in the form of hard data or through experts. Institutionalization means that company's principles and strategies should be stored in a way that new people will be able to learn these easily thus maintaining sustainability.

Lean principles can be categorized in terms of three dimensions; people, process and product. There are lessons learnt while transforming to lean approach considering each dimension individually provided in [28] (see Table 5).

Table 5: Lessons Learn During Lean Transformation

Dimension	Lessons Learn
Process	Guide the team but give them freedom to choose their process.
	Ensure that applied processes are right by giving the team freedom.
	Break the monotony and renew the processes.
	Focus on continuous improvement by reducing waste and adding value.
People	Keep the team members self-responsible by giving them opportunity to act as a tact speaker for a day.
	Team members should be able to pick up the knowledge on their own and there should be role rotation.
	Appreciate the whole team instead of an individual.
Product	Improve quality of internal artifacts which affect external behavior to get early investments.

RQ1: Which methods have been used so far to apply lean principles to product development?

There are many tools and methods used by different organizations to apply lean concepts in their development systems. Lean has been used in many contexts in different organizations. Lean thinking has been applied in IT service innovation, designing websites and in management perspectives.

Moreover, different systems like Manufacturing Execution System (MES) and Enterprise Resource Planning (ERP) use lean in parallel to their own functions to achieve high performance. There are certain tools proposed to access leanness of organizations and to implement lean principles in a sustainable way.

Various tools, models, methods and frameworks corresponding to different lean contexts are listed (see Table VI). Only those studies are listed in the table which have clearly defined frameworks, tools, methods and models regarding different concepts of lean. Brief descriptions are also provided for them. Their findings are listed to get insight of various lean concepts and to identify certain research gaps for future considerations.

Table 6: Analysis of Different LPD Concepts Regarding Models/Tools/Frameworks

Ref.	Concept	Contribution	Description	Finding
[1]	Use of lean principles in IT service innovation	Conceptual Framework	Analyzed the lean principles using case study of service organization	There should be enough openness between two organizations to facilitate innovation
[20]	Design of reward-based crowdfunding website	Lean Product Process Framework	Persona, Kano Model, Product Value Proposition, User Stories, User Experience Design Framework, & Usability Testing	Minimum viable product (MVP) is obtained by involving users
[21]	Lean software product management (SPM)	Erlang-C Model accompanying case study	Evidence-based decision making approach; use of Kanban in Software development	Provides decision making process for SPM
[22]	Effect of each lean principle on performance	Core benefits of each lean principle	Lean enablers are mentioned corresponding to each principle & Enablers Enablers are mapped to lean metrics (implementation & Program) to measure performance	Give suggestions of what to measure to check performance
[16]	Lean Management (LM) Dimensions	Conceptual model	Model has input, transformation & output phase	Analyzed that there are 7 dimensions of LM

[23]	Achieve effective leanness in development process	Compact teams (CTs) model accompanying case study	CTs differs from traditional PD in terms of team size, functional organization & No. of projects assigned to a designer	Significant performance benefits
[24]	Manufacturing execution systems (MES) support for lean production	5 stage capability maturity model (CMM)	Describes that how MES can be used to support lean production principles	Shows that CMM has its influence on both practical implementation & theoretical knowledge
[25]	Lean service management	Lean management Framework	Framework has five phases. Each phase having 3 principles	Analysis helps service companies to apply lean management in their operational business
[26]	Effect of human factor in lean management	Research model	Model takes individual characteristic as its input	To achieve long-term performance of lean, individuals should be given attention regarding both technical and soft practices
[6]	Assessing negative side effects of lean management	Multi-perspective assessment method	Identify negative effects and their root causes	This method can monitor, detect and overcome negative side effects
[18]	Implement lean in a sustainable way	Lean assessment tool	It has 24 criteria having 4 important factors; culture, leadership, knowledge and process. These are further sub-divided.	Certain countermeasures help to assess leanness but they vary from company to company
[27]	Assessing company's structure before applying lean	Lean product & process development performance measurement tool	Provides companies with a readiness framework to access their status before transforming to lean	Provides a sufficient framework to access development practices

RQ2: What is overall research productivity in this domain?

This is the main research question focusing on determining overall research productivity in Lean Product Development (LPD) domain so that future research will be made easier because

the influential studies of this domain have already been highlighted. To answer this research question, chronological distribution of selected primary studies having time span (2013 to Jan-2018) is plotted (see Figure 2). This distribution shows that most of the studies on LPD are being in year 2013 and 2014, whereas same trend goes for both 2015 and 2016 having six significant studies each. There are four primary studies of LPD in 2017 and only one in 2018. So, 2013 and 2014 can be regarded as most productive years following 2015 and 2016. It can be clearly seen that the research interest in LPD has been decreased over the years which also justifies the need for systematic literature review in LPD. The result are shown after performing qualitative analysis in which we have applied the inclusion, exclusion and quality criteria mentioned in research method.

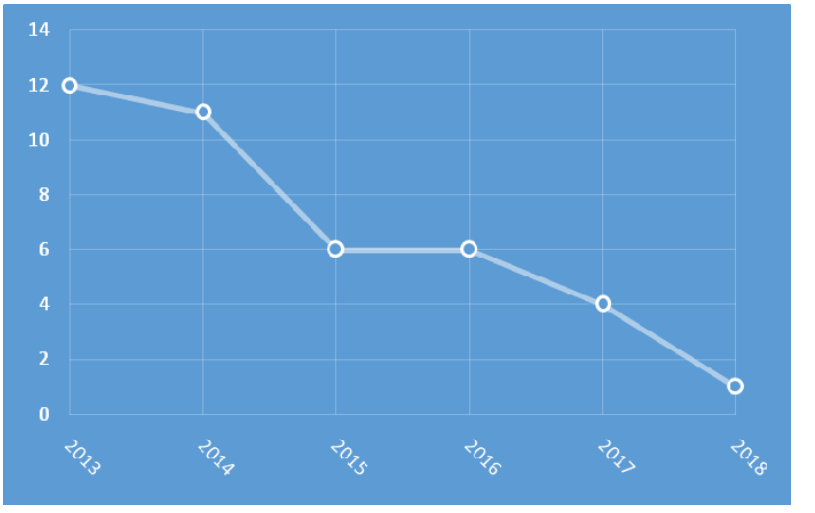

Figure 2: Chronological Distribution (2013-2018)

4 Conclusion

Lean product development is very effective to improve overall quality of development. Lean principles have their impact on all stages of development employing its seven principles. Lean surpasses other development processes by avoiding unnecessary features and only focusing on those as demanded by the customers thus increasing customer value. It delivers as fast as possible by working in iterations to get immediate feedback so that changes can be avoided thus reducing overall cost. Overall research productivity of this domain has been analyzed. In this SLR, lean product development has been discussed considering certain contexts. Moreover, methods used for lean development by different organizations in various contexts have been listed. In the extended version of this SLR, details will be broadened and remaining research questions will be given comprehensive consideration.

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